BERRIE et al.

ECOLOGICAL STUDY OF THE RIVER LAMBOURN.

title

REPORT FOR THE PERIOD

October 1970 to March 1972

University of Reading

Department of Zoology

CONTENTS

PREFACE

The south-east of England has the lowest rainfall, the highest evaporation rate and the highest population density in the British Isles. Conservation schemes are necessary to ensure an adequate supply of water for the growing domestic, agricultural and industrial requirements and particularly to maintain the supply throughout occasional, prolonged periods of dry weather. By 1981 the non-returnable demand for water abstraction from the River Thames is expected to be about 398 million gallons per day and a balance of at least 170 million gallons per day must be discharged into the estuary to prevent stagnation and undesirable ecological and amenity problems. The resources of the river and its associated storage reservoirs will fall short of this total by about 102 million gallons per day during a drought year. Land values are high and the topography of the area is not very suitable for constructing large surface reservoirs. The chalk strata in some parts of the Thames catchment contain natural underground stores of water and the Thames Conservancy have devised a plan to utilise these reserves during dry periods. The water would be pumped to the surface and discharged into various tributaries to maintain an adequate flow for abstraction in the lower reaches of the Thames. The underground water supplies the springs which produce most of the natural flow in the rivers in these chalkland areas. These chalk streams are famous for their trout fishing and are an important component in the ecology and natural beauty of the areas. In planning and developing the ground-water pumping scheme consideration has been given to the possible hydrological and ecological effects. The scheme is designed to make extra water available at times of severe shortage and, if it is used so extensively that severe hydrological changes are produced, it would probably no longer be able to meet such an emergency. If the hydrological changes are small it is possible that any ecological effects will be subtle rather than dramatic and consequently difficult to detect. Few detailed studies have been made on the ecology of the chalk streams. A complex community of plants and animals is present and much more information is required to achieve an understanding of the requirements and interactions of all the species. It is important that the rivers affected by this scheme should be studied and kept under continued observation so that any effects produced by the scheme can be detected. This need has been recognised by the Thames Conservancy and the Water Resources Board who have jointly sponsored this investigation on one of the chalk streams involved in the scheme.

STAFF LIST

Project Director

A. D. Berrie, B.Sc, Ph.D. (Glasgow)

Senior Research Assistants

J. F. Wright, B.Sc., Ph.D. (Wales)

P. D. Hiley, B.Sc.(Newcastle)

Research Assistants

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M. Elizabeth Wigham, B.Sc.(Reading) (from 10th May 1971)

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Penelope R. Gibson, B.Sc.(London) (from September 1971)

Research Students

G. P. Green, B.Sc.(Reading)

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Vacation Student

D. C. F. Cotton (July-August 1971)

Secretary (part-time)

Caroline E. Andrews (until June 1971)
Sylvia G. Page (from October 1971)

INTRODUCTION

1.1 AIMS

A small investigation of the ecology of the Lambourn was carried out during 1967-70 with a grant from the Water Resources Board. During this period it became clear that detailed and reliable information could only be obtained by a much larger investigation. The present study was planned to meet the minimum requirements and is financed jointly by the Thames Conservancy and the Water Resources Board for the period 1970-73. No pumping is expected during this period and, since the pumping carried out during the pilot scheme was on a small scale, it is reasonable to assume that the river is still relatively unaffected by pumping. The present investigation has two main objectives both of which depend on obtaining a detailed picture of the ecology of the river at the present time. First, it will provide basic information on the state of the river prior to the development of the pumping scheme which will be available for comparison at any later date. Secondly, it may be possible to use some of the data to predict the ecological changes which may occur if the flow of the river is altered by the pumping scheme.

1.2 STAFF AND ORGANIZATION

The team which has been recruited to carry out the project is shown in the staff list. It was originally intended to have one senior research assistant concerned with the invertebrate programme and the other concerned with the fish programme. In practice the strongest candidates were people with experience of invertebrate groups and the difficulties of mounting an adequate invertebrate programme have made it advisable to leave them both in this field.

Dr. Wright, who has previous experience of chironomids and triclads, joined the team after holding a post-doctoral fellowship in Canada. Mr. Hiley came from the University of Newcastle-upon-Tyne where he was engaged on a study of the taxonomy and distribution of certain caddis larvae. Since chironomids and caddis larvae are important components of the fauna of the Lambourn their previous experience has been valuable. They are supported by two research assistants. Miss Hynes had just completed an M.Sc. in Ecology and her first degree was in Botany. Mrs. White had gained previous experience in our research project on the River Thames and returned to that after six months when she was replaced by Mrs.Wigham another of our own graduates These four members of the team work largely as a central group concerned with the studies of macrophytes and invertebrates. The third research assistant post was only part-time in the first year and provided general help with the field work.

Miss Gibson was appointed on a full-time basis after graduating from Bedford College, London, and is engaged on a study of the diet and fecundity of trout and grayling. The two research students have important lines of work of their own. Mr. Green is one of our own graduates and he is investigating the ecology of bullheads and ammocoetes. Mr. Scorgie came on completion of an M.Sc. in Ecology having taken his first degree in combined Botany and Zoology. He is investigating the food of the invertebrate fauna of the river. Population studies on trout and grayling are carried out by Dr. Berrie.

1.3 LABORATORIES AND EQUIPMENT

The team has the use of an office, which is shared by the two senior research assistants, and two small research laboratories in the new Department of Zoology which was completed in March 1971. The soil washing facilities have proved very useful for the initial processing of field samples, but protracted difficulties with constant temperature rooms have hindered the rearing of adult insects for identification and studies on the growth rates of the invertebrates. Delays in delivery of equipment provided some further difficulties but none has proved insurmountable. The only major failure has been to obtain some of the equipment for monitoring physical information about the river. This resulted from inadequacies of the available equipment and the failure of manufacturers to actually bring promised new items on to the market. The team has the use of a Land Rover which covered some 11,250 miles during the period.

1.4 FIELD PROGRAMME

A major difficulty of studying trout and grayling in the Lambourn is the fact that many of the owners stock trout into the river and some remove grayling. It was essential to obtain control of the fishing in part of the river if reliable data were to be obtained. For this reason part of the river near Bagnor village has been leased for three years. The agreement covers the river from the Watermill Theatre down to Donnington Grove (Fig. 1) and came into effect on 1st January 1971.

In this area the river is divided into two channels of which the northern is the more interesting. For most of its length it is of wadeable depth and has a reasonably fast flow. It flows through areas which are unshaded, lightly shaded and heavily shaded and includes areas with different patterns of plant growth. It is joined by the Winterbourne which is of considerable interest in relation to the pumping scheme. The northern channel has a total

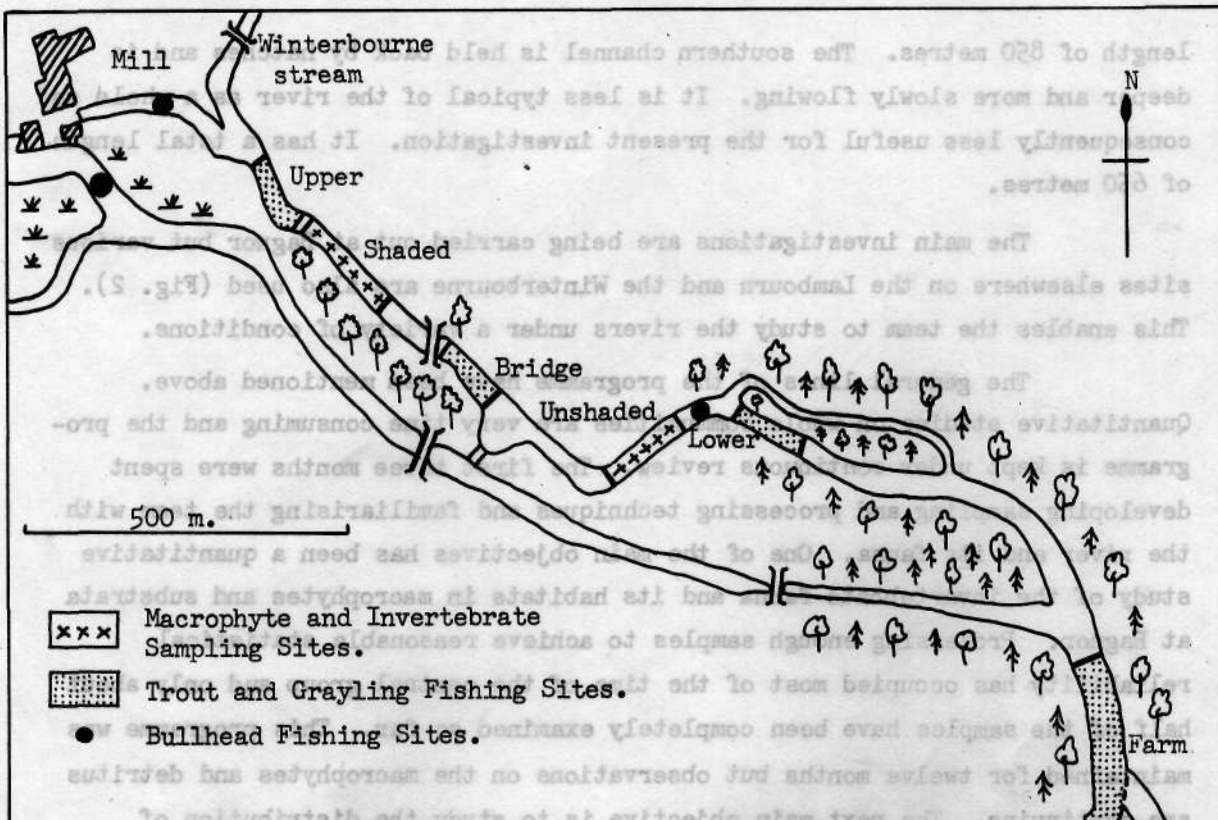


Figure 1. The River Lambourn at Bagnor.

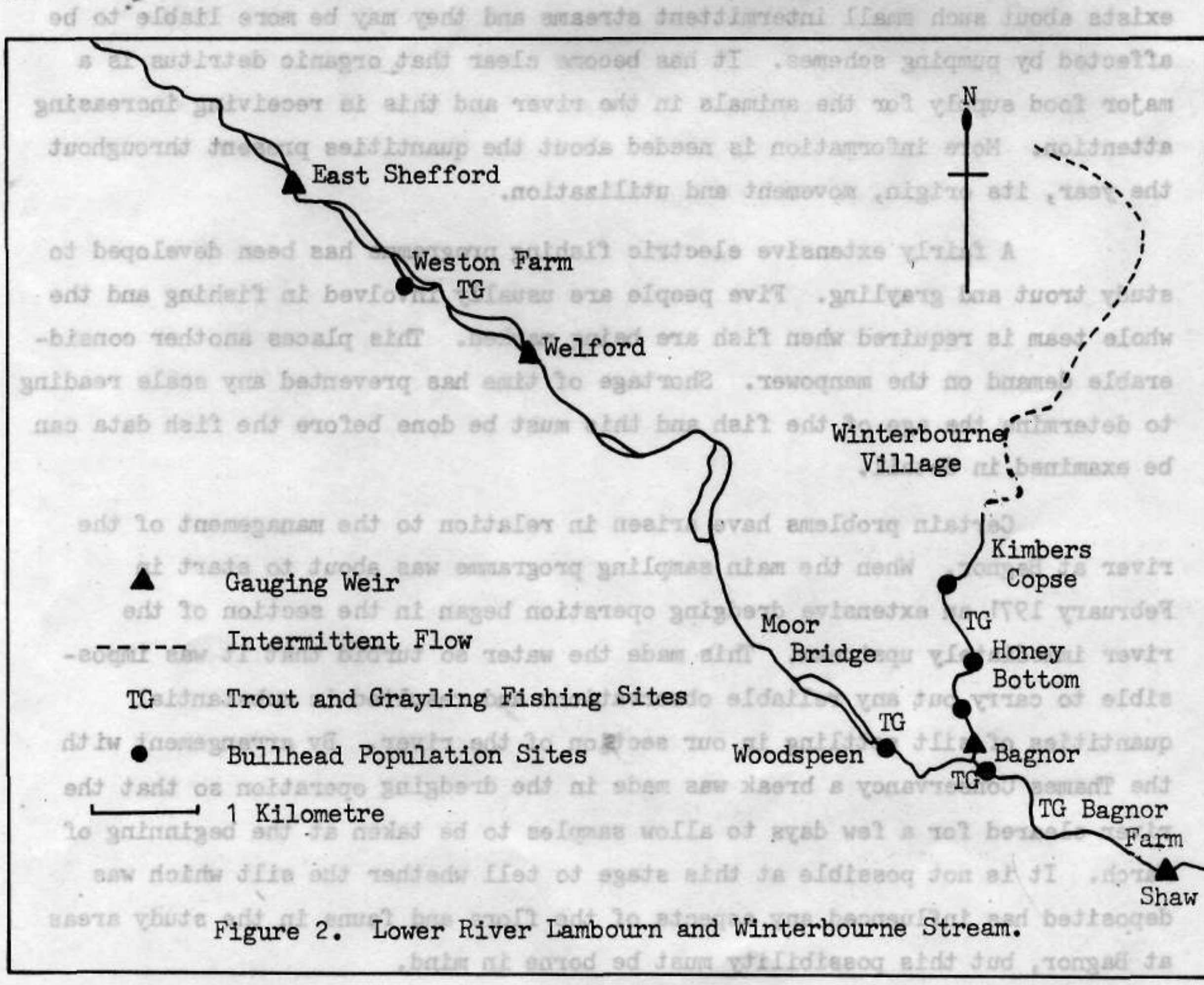


Figure 2. Lower River Lambourn and Winterbourne Stream.

length of 850 metres. The southern channel is held back by hatches and is deeper and more slowly flowing. It is less typical of the river as a whole and consequently less useful for the present investigation. It has a total length of 650 metres.

The main investigations are being carried out at Bagnor but various sites elsewhere on the Lambourn and the Winterbourne are also used (Fig. 2). This enables the team to study the rivers under a variety of conditions.

The general lines of the programme have been mentioned above. Quantitative studies on whole communities are very time consuming and the programme is kept under continuous review. The first three months were spent developing sampling and processing techniques and familiarising the team with the river and its fauna. One of the main objectives has been a quantitative study of the invertebrate fauna and its habitats in macrophytes and substrata at Bagnor. Processing enough samples to achieve reasonable statistical reliability has occupied most of the time of the central group and only about half of the samples have been completely examined so far. This programme was maintained for twelve months but observations on the macrophytes and detritus are continuing. The next main objective, is to study the distribution of invertebrates along the Winterbourne for a year. Practically no literature exists about such small intermittent streams and they may be more liable to be affected by pumping schemes. It has become clear that organic detritus is a major food supply for the animals in the river and this is receiving increasing attention. More information is needed about the quantities present throughout the year, its origin, movement and utilization.

A fairly extensive electric fishing programme has been developed to study trout and grayling. Five people are usually involved in fishing and the whole team is required when fish are being marked. This places another considerable demand on the manpower. Shortage of time has prevented any scale reading to determine the age of the fish and this must be done before the fish data can be examined in detail.

Certain problems have arisen in relation to the management of the river at Bagnor. When the main sampling programme was about to start in February 1971 an extensive dredging operation began in the section of the river immediately upstream. This made the water so turbid that it was impossible to carry out any reliable observations and resulted in substantial quantities of silt settling in our section of the river. By arrangement with the Thames Conservancy a break was made in the dredging operation so that the river cleared for a few days to allow samples to be taken at the beginning of March. It is not possible at this stage to tell whether the silt which was deposited has influenced any aspects of the flora and fauna in the study areas at Bagnor, but this possibility must be borne in mind.

It is normal practice to cut the water weeds in the river during each summer although the extent and method varies. There is normally at least one main cut with a second cut taking place in years of heavy growth, but some owners prefer to have a series of lighter cuts. It would clearly be misleading not to cut weed in the study areas and weed cutting has been arranged at times which will cause the least disturbance to the sampling programmes.

1.5 ACKNOWLEDGEMENTS

This investigation is financed by the Thames Conservancy and the Water Resources Board and we receive valuable co-operation from various members of their staff, particularly Mr. E. J. Brettell, Mr. H. Fish, Mr. B. J. Hardcastle, Mr. A. J. Miller and Mr. J. C. Peters. We are grateful to the Piscatorial Society and Mr. J. Gladstone (Donnington Grove) for allowing us to lease the fishing at Bagnor and to Mr. R, D. Lawson (Piscatorial Society) for his help with management problems. Mr. R. Mead (University of Reading) has provided advice on the design of the sampling programme. We are also indebted to the landowners listed below who allow us access to their land and water. Our requests have always been received with courtesy and without this help our study would not be possible.

Mr. D. Abbott (Hazelhanger Farm)
Lady Jean Ashcombe (The Mill House)
Mr. A. R. Baylis (Winterbourne Manor)
Mr. D. R. Baylis (North Heath Farm)
Mr. D. A. W. Gardiner (Newbury)
Mr. J. E. Hanson (Kimbers Copse)
Marshall Brothers (Pit King Farm)
Mr. T. Pocock (Woodspeen Farm)
Mr. C. Povey (Winterbourne Farm)
Mr. & Mrs. J. L. Puxley (Welford Park)
Mr. D. Rolt (Chieveley Manor)
Mr. E. J. Saunderson (Honey Bottom)
Mr. F. Stallwood (Kintbury)
Mr. W. E. Wallace (Bagnor Manor)
Mr. G. Wallis (Weston Farm)

2. PRELIMINARY INVESTIGATIONS

The first few months were spent developing methods and apparatus capable of sampling the macrophytes, invertebrates and substrata in the River Lambourn. Chalk streams contain a wide variety of habitats, often within a short distance of each other, and different sampling methods may be required in each case. Sampling equipment is often designed for a particular habitat and may be quite unsuitable elsewhere.

Gravel sampling presents difficulties due to the fact that animals penetrate some distance below the surface. It is therefore necessary for the sampler to penetrate the gravel in some way. The growth forms of the three main species of macrophytes are different. Berula grows as short, individual plants whereas Ranunculus may consist of long trailing growths from relatively short rooted areas. Callitriche may form dense mats at the surface with stems extending down to roots in the substratum. A decision must be reached on whether these macrophytes should be sampled separately from the riverbed, or as an integral part of it. In either case the difficulty is to enclose a representative portion of the macrophyte which may be up to 0.5m thick.

Samples taken from the field consist of a number of components, each of which must be separated and processed further. Existing methods generally dealt with the separation of only one component from the others. The problem was, therefore, to develop a procedure which integrated methods of separating each component.

2.1 SAMPLING TRIALS ON MACROPHYTE

2.1.1. Box Samplers

A box sampler for river macrophytes is illustrated in Fig. 3a. The base plate is placed under the weed and the box, which is deeper than the water, is forced down on to the plate, enclosing a sample of weed. The box is secured to the base and the weed stems cut around the edge of the box, enabling the sampler to be removed from the water. The water drains through the perforations in the base, and a sample of trailing weed of known area, together with the associated animals, is obtained.

The relative efficiency of two sizes of sample was tested using models enclosing $0.1m^2$ and $0.04m^2$ respectively. One $0.1m^2$ and two $0.04m^2$ samples were taken in close proximity on an area of weed of apparently uniform density. If uniform density is not assumed it becomes necessary to take large numbers of samples from a wide variety of weeds to obtain a meaningful result. Such groups of three samples were taken twice in Ranunculus and four times in Callitriche. Figures for the dry weight of weed, and the number of animals of

TABLE 1 Examples of species obtained with Box Samplers, expressed as numbers per gram (dry weight) of weed. (30/10/70).

	Callitriche		Ranunculus	
	$0.04m^2$ (8 samples)	$0.1m^2$ (4 samples)	$0.04m^2$ (4 samples)	$0.1m^2$ (2 samples)
Hydra spp.	7.6	9.7	ii.5	1.8
Oligochaeta	5.2	1.1	-	-
Potamopyrgus jenkinsi	29.0	30.0	-	"
Physa fontinalls	0.2	0.3	0.1	0.3
Planorbis spp.	0.2	0.2	-	-
Piscicola geometra	0.4	0.3	-	-
Gammarus pulex	8.1	8.9	3.2	6.0
Paraleptophlebia submarginata	0.1	0.3	-	-
Ephemerella ignita	3.8	3.7	0.5	0.6
Baetis spp.	6.2	3.0	2.7	2.2
Heptagenia sulphurea	-	-	0.5	0.7
Hydropsyche spp.	-	-	0.1	0.1
Hydroptilidae	27.0	31.0	0.5	0.2
Potamophylax sp.	1.0	0.5	-	-
Lepidostoma hirtum	4.8	0.7		-
Total No. animals	112.6	99.6	19.3	l4.6
Mean No. species per sample	11.0	12.25	11.5	13.25

each species or group, were obtained for each sample. The larger sampler collected an average of 36% more weed per unit area than the smaller. As shown in Table 1 the number of animals of each species per gram of weed is similar for both sample sizes. The number of species collected in the larger sample is higher than in the smaller due to the increased chance of collecting less common species.

It proved impossible to take samples from rooted areas of Berula and Ranunculus without enclosing varying amounts of the substratum.

2.1.2 Saw-Cylinder Sampler

This sampler was designed for use in Phragmites swamp. It consisted

of two concentric cylinders joined together, the inner being 0.031m in cross-section. The space between the outer and inner houses a mechanism to project four blades into the inner cylinder near the base of the sampler. A cutting edge is mounted at the basal end of the inner cylinder, and the outer cylinder is

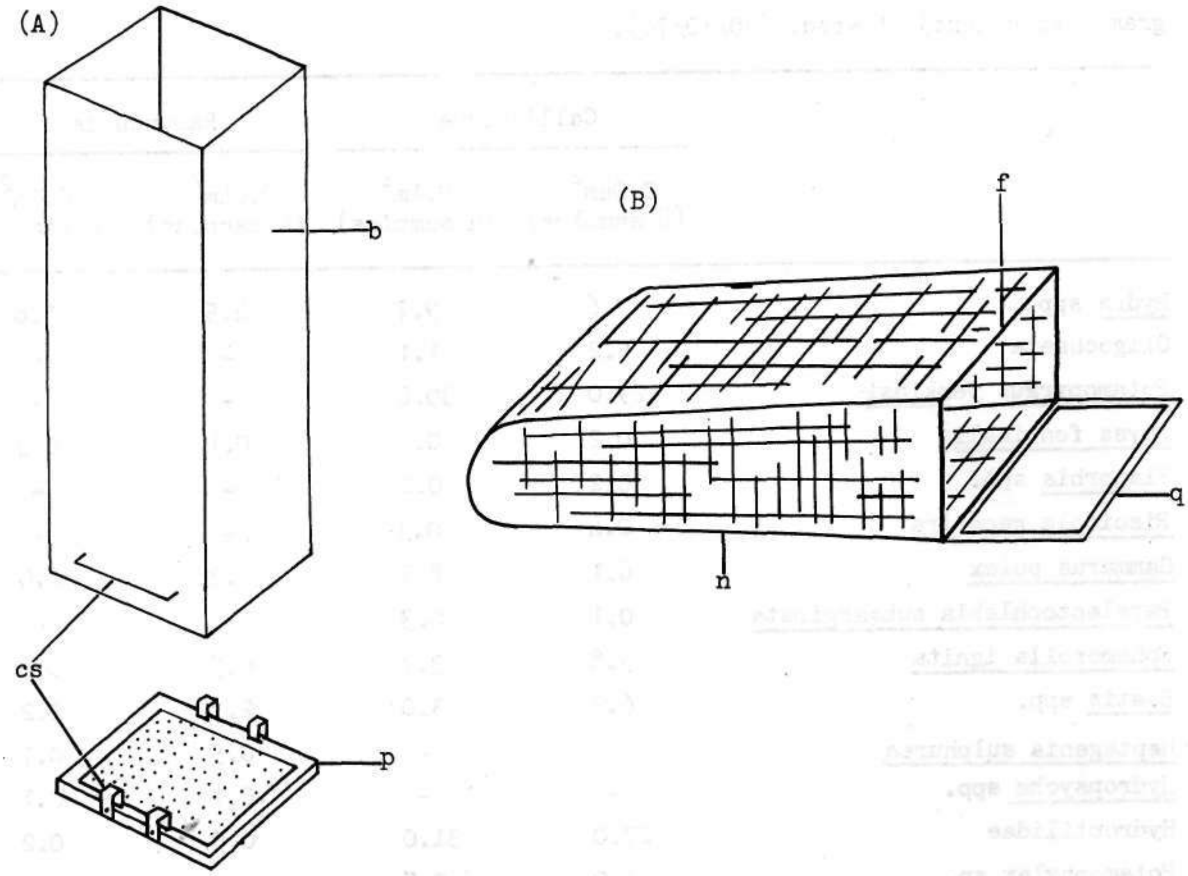


FIGURE 3; (A) Box Sampler. b = Alloy box open at both ends, p = perforated base plate, cs = clamp system. (B) Surber Sampler. f = vertical frame, n = 40 mesh nylon net, q = quadrat frame.

tapered to meet the inner at this point. Rotation of the sampler as it is forced vertically into the substratum causes the cutting edge to sever weed roots. Projection of the blades into the inner cylinder then cuts the weeds below their main stems and enables the sampler to be removed together with the contained plug of material. The material may then be washed from the sampler into a suitable receptacle. Tests of this sampler in the river failed to locate areas where the depth of detritus was sufficient to allow the blades to operate below the weed stems.

2.1.3 Net Samplers

Two methods of obtaining large quantities of weed of unknown area were tested. The results of such samples are expressed as animals per gram of weed. A 0.6m square polythene bag was used to enclose part of a trailing weedbed, the weed being then cut at the mouth of the bag. Trials showed that eddy currents around the bag prevented much of the fauna from entering the bag, and often swept material out of the bag.

A 460mm long net was attached to a 460mm square metal frame, and used to take three swathes through rooted weed. The frame was held vertically with the lower edge touching the substratum. The weed immediately upstream was cut close to the substratum, and the net advanced to capture the cut weed. It was very difficult not to disturb the substratum and thus include detritus fauna in the sample.

2.2. SAMPLING TRIALS ON GRAVEL

2.2.1 Grab Sampler

Experiments were made with a sampler, which is basically a Petersen grab mounted on a pole, to ascertain its use in the Lambourn. Difficulty was experienced in obtaining a sample on all substrata tested, due to large particles becoming lodged between the jaws and preventing closure. No samples were taken which were complete enough to justify analysis.

2.2.2. Surber Sampler

The Surber sampler (Fig. 3b) consists of a quadrat frame which is laid on the substratum, and a vertical frame which holds a net against the downstream edge of the quadrat. The gravel enclosed by the quadrat is scooped into the net, and the flow of water helps to wash dislodged animals into the net. Tests of this method were carried out using 0.1 and $0.0625m^2$ sample areas. Observations during the sampling indicated several sources of error. Material from outside the sample area can fall into the area during excavation, and material drifting downstream from above the sample area can enter the net. Detritus and animals sometimes escape round the net, and animals could also escape via the gravel interstices. The results of these samples (Table 2) showed a rather large variance, and it was initially thought that this reflected faults in the samplers.

TABLE 2 Examples of species taken in 10 surber gravel samples, expressed as Numbers per m^2. (15/10/70).

	Mean	Variance	Standard Error
Gammarus pulex	2736	241330	491
Silo nigricornis	537	64935	81
Agapetus spp.	7730	141300648	3759
Dicranota spp.	67	22934	17

It was later seen (Table 4) that probably only <u>Agapetus</u> was being inadequately sampled by this method.

2.2.3. Kick Samples.

The theory of kick-sampling is that the river bed is disturbed with the feet immediately upstream of a net held vertically with its lower edge touching the substratum. The current washes dislodged animals into the net. In order to compare the results of such sampling, four standardised samples were taken from an even looking area of gravel. Four parallel strips of equal length running upstream were marked out and sampled consecutively, spending the same time sampling each strip. The results (Table 3) indicate the relative proportions of the species collected by the technique, but give no estimates of numbers per unit area. These results may be compared with quantitative estimates of gravel fauna given in Table 4.

TABLE 3 Examples of species captured by kick samples, expressed as Numbers per sample. (27/10/70)

	Sample Number			
	1	2	3	4
Gammarus pulex	163	343	170	122
Baetis spp.	1	8	16	6
Ephemera danica	4	4	1	0
Heptagenia sulphurea	9	22	12	6
Silo nigricornis	8	6	0	11
Agapetus spp.	113	68	286	425
Simulium spp.	0	0	0	0
Oligochaeta	15	9	0	0

Kick sampling was not used in the main invertebrate programme because of the qualitative nature of the results, as well as the possible bias towards sampling some groups less effectively than others. (e.g. *Simulium* and *Silo*)

2.3 PRELIMINARY DESIGN OF METHODS FOR PROJECT USE

2.3.1. Choice of Size of Sample

The greatest amount of labour in processing a sample is expended on picking the animals from the sample. It is desirable, for statistical purposes, to take as many samples as possible. Thus the smaller the sample size, the more may be processed in the time available. Several factors govern the lower size limit:-

1. The sampler should be considerably larger than the largest particle encountered (about 150mm)so that no habitat is missed.
2. The weed is needed for analysis and, as shown in Section 2.1.1., efficiency in estimating weed biomass falls with sample size decrease.
3. Size distribution data is required for the more abundant invertebrates, and this needs around 100 animals of each species to be captured in each sample. The average number of the commoner species obtained in 24 test samples is shown in Table 4. The relative abundance of these, and groups not listed, will vary considerably according to season.
4. Sufficient room should be available inside the sampler to enable the operator to take a 95mm diameter core of the enclosed material, then scoop the remaining material into the net.

The sample size chosen was $0.05m^2$ since it fitted well to the above requirements.

TABLE 4 Examples of species taken in $0.05m^2$ Test Samples, expressed as Numbers per Sample. (18/11/70).

	Mean		Variance		Standard Error/Mean %	
	Gravel	Berula	Gravel	Berula	Gravel	Berula
Oligochaeta	27.00	134.00	358.00	16144.00	20.00	29.00
Baetis spp.	41.00	7.00	648.00	97.00	18.00	42.00
Heptagenia sulphurea	6.00	6.00	20.00	31.00	20.00	28.00
Ephemera danica	3.00	68.00	15.00	1127.00	42.00	15.00
Silo nigricornis	24.00	-	183.00	-	16.00	-
Agapetus spp.	185.00	-	4804.00	-	11.00	-
Hydropsyche spp.	0.9	13.00	0.6	562.00	24.00	55.00
Hydroptilidae	0.9	98.00	1.5	9590.00	39.00	30.00
Simulium spp.	27.00	124.00	1603.00	3800.00	43.00	15.00
Gammarus pulex	361.00	491.00	9150.00	15802.00	7.65	7.71

2.3.2. Box Samplers

A $0.05m^2$ box sampler was designed and built (Fig. 4a). It functions on the principle outlined in Section 2.1.1., Fig. 3a. Correct positioning of the box on the base is ensured by passing the upright guide rods through the lugs on either side of the box. The two parts of the sampler are held together by wing nuts which may be dropped down the guide rods, then screwed on to the threaded part with a special tool. The action of the steel cutting edge against the rubber pad severs most weed stems.

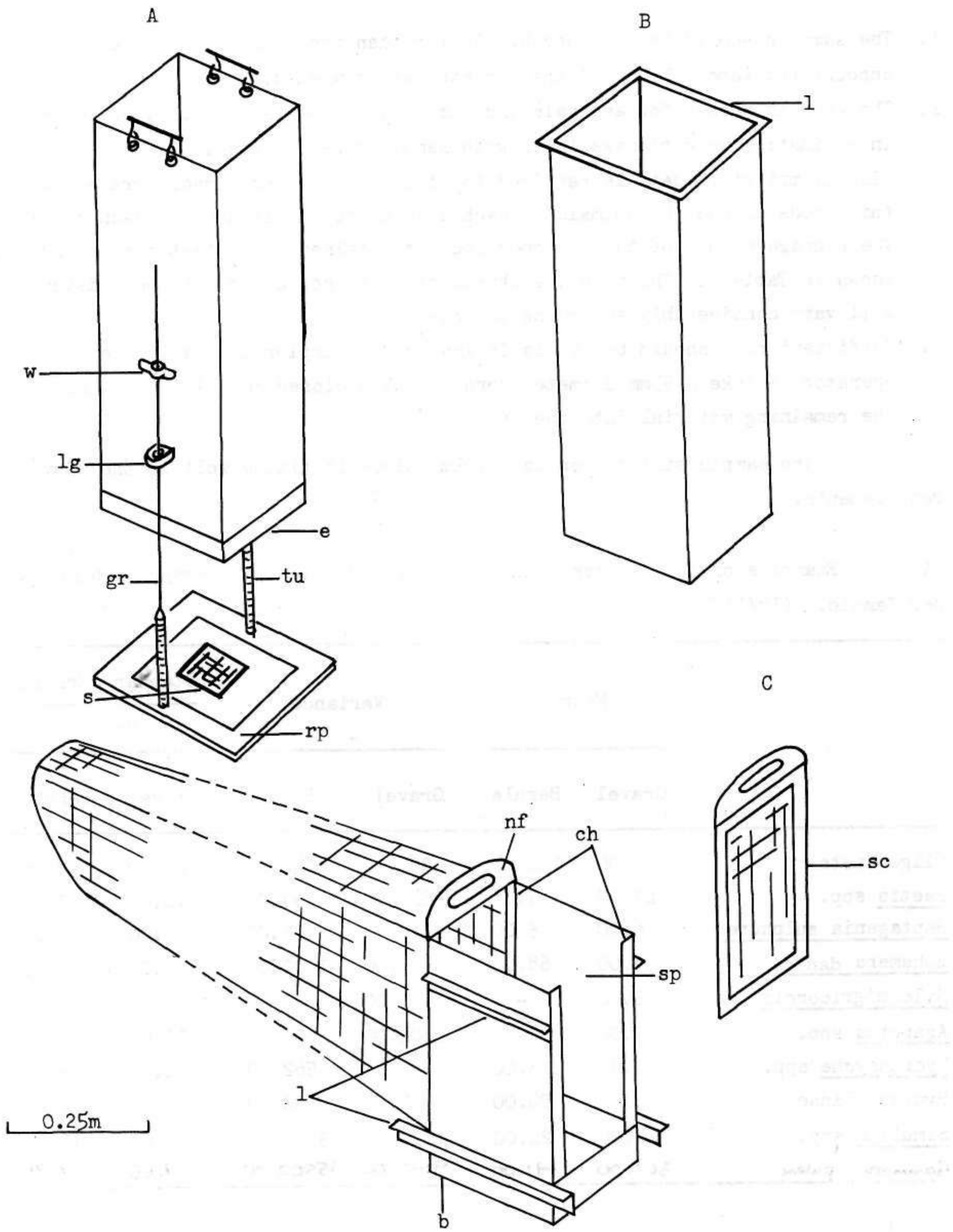


Fig 4 (A) Box Sampler. w = wing nut, lg = lug, e = steel cutting edge, gr = guide rod, tu = threaded upright, s = 40 mesh metal screen, rp = rubber pad. (B) Open Ended Box Sampler. 1 = ledge. (C) Modified Surber Sampler. nf = net frame, ch = channels, sp = side plates, 1 = ledges, sc = front screen, b = steel base.

A simple $0.05m^2$ box, open at both ends (Fig. lib) was made to enable samples to be taken in areas of rooted weed where there is slow flow or deep silt. The box is pushed vertically into the substratum as far as possible and the enclosed material bailed into a large 40 mesh net with a small 40 mesh hand net. Agitation of the large net underwater causes fine detritus to be washed through, thus concentrating the sample, which can then be transferred to a suitable container.

2.3.3. Modified Surber Sampler

This $0.05m^2$ sampler (Fig. 4c) was designed to try and overcome the faults listed in Section 2.2.2. It consists of a steel base, 250 x 200 x 80mm, supporting an alloy framework. The 40 mesh net is lm long and is mounted on a frame which slides in channels situated on the downstream face of the sampler. Sheet metal screens on the lateral faces prevent material escaping round the net. A removable 40 mesh gauze screen on the upstream face prevents drifting material entering the sampler but allows a through current to carry the sample into the net. As the sampler is being lowered into position in fast water there is a tendency for it to increase the flow of water over the substratum directly beneath it. To prevent this scouring effect the sampler is moved downstream at the same'' speed as the current while it is being lowered. The sampler is forced into the substratum, using hand and foot pressure on the ledges, until the lower ledge rests on the gravel surface. The enclosed material is then excavated until the lower edge of the base is exposed. Further excavation would cause undesirable caving in of extraneous material. Agitation of the remaining material causes animals to be stirred into suspension and thus be washed into the net by the current. The net may then be removed from the sampler and the sample transferred to a suitable container on the bank.

2.3.4. Number of Samples from each Substratum.

Twelve samples were taken on the same day in an even looking area of Berula with the O.O5m open-ended box sampler. A further twelve samples were taken in similar fashion with the $0.05m^2$ modified surber sampler on gravel. The number of animals of each species in each sample was noted, and the mean, variance and standard error for each of the more abundant species in either set of samples were calculated. (Table 4).

The relationship of the standard error to the mean gives an estimate of the efficiency of a particular number of samples in estimating the population of a species. Figures of 20% or less indicate efficient sampling in freshwater benthic studies. The number of samples necessary to estimate a population of a species to this level will therefore depend on the variance, which is an expression of the type of distribution shown by that species. The distribution of most freshwater invertebrates is clumped, as indicated by the variance exceeding the mean. The degree to which this occurs varies considerably, both with species, and with substratum. It was not practicable to take sufficient samples to estimate every species to the 20% level, but it was possible to do this for the more important species, such as Gammarus, Agapetus and Ephemera, where these are represented by more than ten animals per sample. On the basis of the data in Table 4 it was decided that ten samples per substratum was adequate.

Determination of the minimum number of samples necessary to estimate the invertebrate population of a substratum enabled a decision to be reached on the maximum number of substrata which could be sampled with the labour available.

2.3.5. Sampling Substrata

Two corers were made to obtain samples for physical analyses of the: substrata in the river. The larger sampler for use on gravel,is a metal tube of $0.007m^2$ cross-sectional area. One end is pushed vertically into the gravel and the upper end is then sealed with a tight-fitting lid. Gravel is then excavated on one side so that a metal plate can be pushed across the open lower end. The plate is held firmly against the open end while the tin is removed from the substratum, inverted and carried to the bank. The sample of substratum complete with fine organic material may then be transferred to a polythene bag. The smaller sampler consists of a $0.001m^2$ cross-sectional area perspex tube, tapered at one end, with a rubber bung to fit the other end. The open tube is pushed vertically into silt substrata and the bung pushed firmly into the upper end. The sample is held in the tube by atmospheric pressure during removal from the river. Removal of the bung allows the sample to slip out into a suitable container.

Two trials in which one $0.1m^2$ Surber and two $0.007m^2$ Core samples were taken close together showed that the size distribution of mineral particles, and the ratios of coarse detritus to mineral matter, were similar. (Table 5).

TABLE 5 Percentage Composition by Volume of Trial Cores

	First Area			Second Area		
	Surber	Core	Core	Surber	Core	Core
Mineral above 10 mesh	63.4	60	69		45	46
Mineral above 20 mesh	13	12	11	11.8	12	13
Mineral above 40 mesh	24	30	20	42.3		40
Organic above 40 mesh	0.6	0.4	0.3	0.4	0.4	0.4
Ratio $\frac{\text{organic}}{\text{mineral}}$ below 40 mesh		1.6	1.2		1.1	0.8

2.4. LABORATORY TECHNIQUES

Samples taken in the field consist of a mixture of macrophyte, mineral, detritus and animals. Picking out the animals from such samples takes a great deal of time, and some rapid means of preliminary separation is desirable. Various methods were tried in order to develop a system which could combine speed and efficiency in processing the raw samples.

2.4.1. Macrophyte

Trials were carried out on a piece of apparatus developed at the Ministry of Agriculture, Fisheries and Food for separating animals from macrophyte. This consisted of a metal tank which had eight diffusing stones fitted inside near the bottom. Compressed air passed through the stones agitated the contained weed sample in water. A flow of water through the apparatus carried animals in suspension over a spillway and into a sieve. Tests with material collected from the River Lambourn showed that separation was not complete and consequently the labour involved in sorting was not decreased greatly. A method of separating the macrophyte by hand was then developed for use in the project.

A fresh sample from the field is placed in a bucket full of water, stirred throughly and left to settle. The macrophyte floats to the surface under the bouyance of air trapped in the tissues. It is scooped up with a small sieve or picked out by hand, and transferred to a bucket of clean water. The remaining water is passed through a 40-mesh sieve to concentrate the debris and animals, which are then treated as described in Sections 2 .4.2. and 2.4.3. The process is repeated with changes of water until no animals are left in the water. A series of tests showed that three such washings normally removed 99% of the animals from the weed. (*Simulium* pupae adhere firmly to the weed and are picked off at a later stage in the process.) The separated macrophyte is stored in a deep freeze since preservatives would interfere with proposed calorific value determinations.

2.4.2. Mineral

Trials were carried out on a piece of apparatus designed by the Water Research Association for separating animals and detritus from mineral matter. It employed a current of water flowing over a system of baffles in a long shallow trough. Material to be sorted was added in small quantities at the top of the trough. Mineral matter settled around the baffles whereas animals and detritus passed through, being collected by sieving the effluent water. The process gave rather incomplete separation with Lambourn material and did not save labour in sorting.

Discussions with other workers gave the impression that flotation with various dense solutions would not be very successful in separating the complex mixture of materials and fauna in the Lamboum samples* Experiments with sucrose solution confirmed this view. Eventually it was decided to use the principle of elutriation as outlined below.

A fresh sample from the field (having had the macrophyte removed where necessary) is placed in a bucket of water, thoroughly stirred by hand and allowed to settle only until most of the mineral fraction is no longer in suspension. The water is immediately poured off through a 40-mesh sieve to collect the animals and detritus. The process is repeated with clean water until no more animals are washed out. The remaining mineral still contains stone-cased caddis larvae. The larger of these are picked by hand from material which does not pass a 5-mesh sieve. The finer material is treated with hot water to kill the larvae, pounded to break up their cases, then rewashed as described above. Other methods of removing caddis from their cases, such as treatment with acids or alcohol, were tried but were not as successful as the process described here.

The mixture of animals and detritus is preserved in 5% formalin until required for further sorting.

2.4.3. Animals

At present there are no methods of separating animals from detritus mechanically, and this must be done by hand. Various stains were used to colour the animals and render them more visible but no stain coloured all the animals in a sample, and other problems were found. Fluorescent stain viewed under ultra-violet light was tried but rejected because of the danger to the operator of long term exposure to such light.

Sorting of animals from detritus is therefore carried out by spreading the sample under water in a large, shallow, white tray and picking out the animals with forceps.

The laboratory processing system for field samples is summarized diagrammatically in Fig. 6.

3 QUANTITATIVE STUDIES ON MACROPHYTES AND INVERTEBRATES IN THE LAMBOURN

3.1. METHODS

3.1.1. Selection of Sites for Intensive Studies

Two contrasted sites, each 50 metres in length, have been chosen for intensive studies at Bagnor. Both sites are located on the northern branch of the Lambourn below the confluence with the Winterbourne and are easily-accessible throughout the year.

The upper site, located upstream of the Bagnor road bridge is partially shaded by a continuous line of trees on the west bank and varies in width between 6.5 and 9.5 metres. A high proportion of the substratum is covered by macrophytes, of which *Berula erecta* is the dominant species, although *Ranunculus* sp. *Callitriche obtusangula* and *Apium nodiflorum* are also well represented.

At the lower site the river flows through open meadowland unshaded by trees and the volume of water is augmented by a pair of adjustable hatches which connect the south and north branches of the river upstream of this site and allow the passage of water into the north channel. The upstream limit of this unshaded site is 7 metres in width and has a deep fast-flowing channel dominated by gravel and *Ranunculus* beds. Downstream the river widens to 13 metres, the current decreases and a greater diversity of macrophytes occurs, including *Berula erecta*, *Apium nodiflorum*, *Callitriche obtusangula* and *Zannichellia palustris*. The upper and lower sites are referred to as the shaded and unshaded sites, respectively.

3.1.2. Mapping the river

Early intentions to use photography as the method of documenting changes in the river were soon rejected due to a number of foreseeable problems including the interpretation of complex mixed weed beds and obtaining the correct exposure in the partially shaded site. It was therefore decided to develop a mapping technique.

Each site was staked at 5m intervals on both banks, and using these permanent markers, additional temporary one metre markers were set up as required for the purpose of mapping each site once a month. The mapping of each site took a team of two approximately one day, but meant that an accurate picture of each site was available for study prior to each sampling operation. The recorder, who remains on the bank, was provided with an appropriate grid drawn out on paper and by setting up another moveable grid over the river, the mapper communicated his observations to the recorder. The moveable grid consisted of two tapes, held exactly one metre apart and having marks along their length at one metre intervals. These were placed across the river and the mapper shouted out changes in the substratum and vegetation every 0.25m in moving along the first tape and then back along the second. By employing two tapes the mapper caused less disturbance in the river and was better able to describe the way in which changes of substratum along one tape linked up with those along the adjoining tape. In the laboratory the map was copied on to a single length of tracing paper to give a map with a scale of 25mm equivalent to one metre. Each one was oyer one metre long and those produced for the shaded site were particularly complex since, unlike the unshaded site, there was a tendency for the macrophytes to occur in mixed beds. Copies were later obtained on transparent film (scale 12.5mm equivalent to 1m) so that a dynamic picture of changes occurring in the river month by month could be obtained by overlaying several maps. Figure 5 shows a short section of one of the maps produced for the unshaded site.

3.1.3. Design of Sampling Programme

Initial examination of the Lambourn at Bagnor led to the conclusion that there were five important habitat types which should be sampled:

1. gravel
2. detritus and sand
3. Berula erecta and Apium nodiflorum
4. Ranunculus spp.
5. Callitriche obtusahgula

Berula erecta and A. nodiflorum were regarded as a single habitat type due to. the similarity of their leaf form and consequent difficulty of separation in the field. Similarly, detritus and sand were considered together since a gradation existed between detritus beds containing a minimum of fine sand, and sand bars with low levels of detritus mixed in or overlaying the surface. Since calculations on the number of $0.05m^2$ samples required per month amounted to a maximum of 50 it was clear that not more than 25 samples per month could be taken from each site. Examination of the first set of two maps, which were made at the end of February 1971, showed that in each site there was considerable variation in the percentage cover of the 5 habitat types. It was, therefore, necessary to decide whether to carry out a sampling programme in which 5 samples would be taken per habitat type in each of the two 50m sites or whether the sampling should be weighted so that the number of samples taken per habitat type related directly to the percentage of each habitat type. Proportional weighting was considered more suitable for assessing the biomass and production in the study area, and equal weighting more suitable for obtaining data which could be used to predict the fauna of areas with different habitat characteristics. In view of the need to consider other parts of the river and the possible effects of pumping it was concluded that equal weighting was the more appropriate approach.

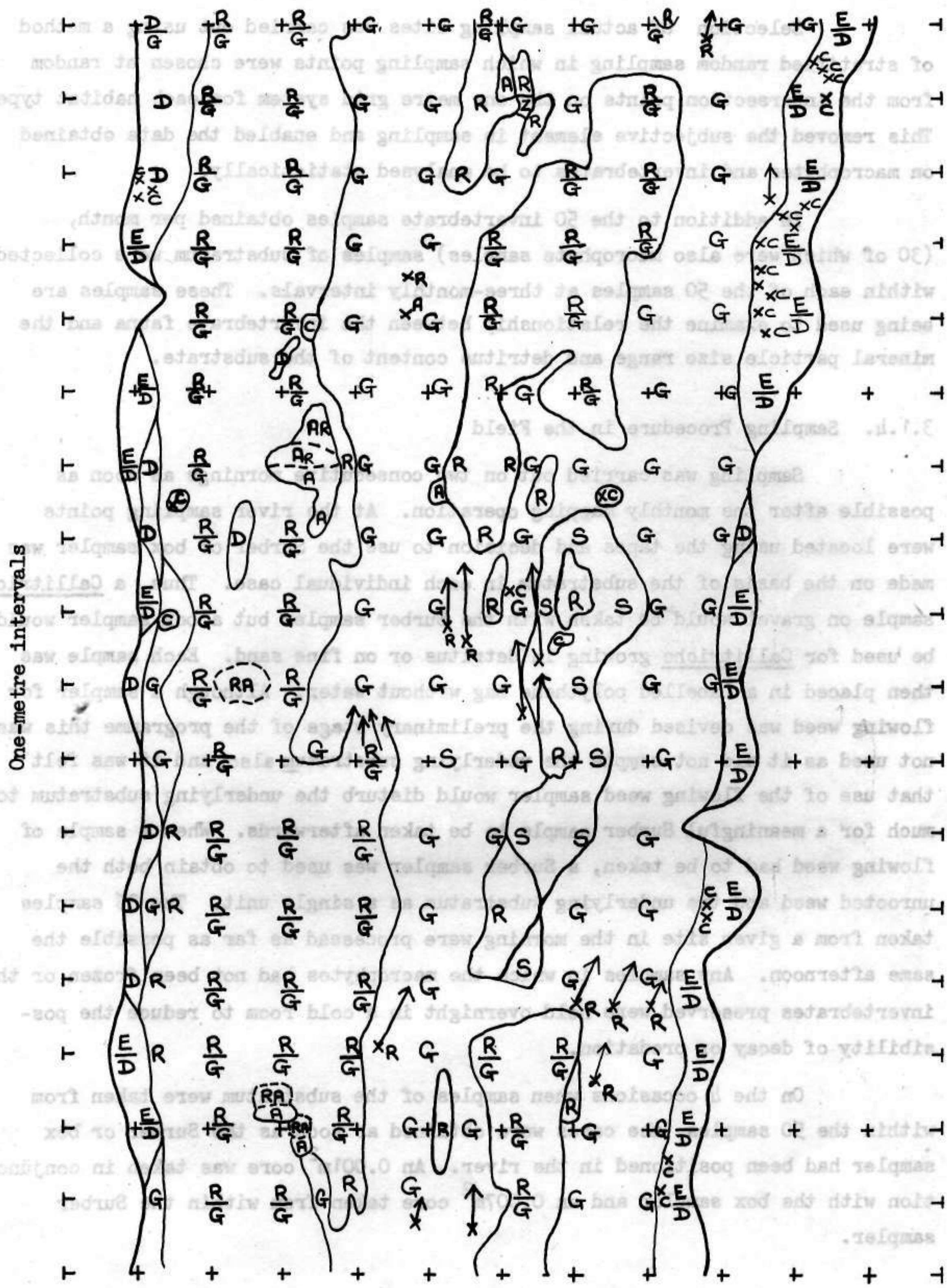


Figure 5. Section of the Unshaded Site Map for July 1971. A = <u>Berula</u>, C = <u>Callitriche</u>, D = Detritus, E = Emergent vegetation, G = Gravel, R = <u>Ranunculus</u>, S = Sand, Z = <u>Zannichellia</u>. Arrows indicate trailing weed.

Selection of actual sampling sites was carried out using a method of stratified random sampling in which sampling points were chosen at random from the intersection points on the one metre grid system for each habitat type. This removed the subjective element in sampling and enabled the data obtained on macrophytes and invertebrates to be analysed statistically.

In addition to the 50 invertebrate samples obtained per month, (30 of which were also macrophyte samples) samples of substratum were collected within each of the 50 samples at three-monthly intervals. These samples are being used to examine the relationship between the invertebrate fauna and the mineral particle size range and detritus content of the substrate.

3.1.4. Sampling Procedure in the Field

Sampling was carried out on two consecutive mornings as soon as possible after the monthly mapping operation. At the river sampling points were located using the tapes and decision to use the Surber or box sampler was made on the basis of the substratum in each individual case. Thus, a <u>Callitriche</u> sample on gravel would be taken with the Surber sampler but a box sampler would be used for <u>Callitriche</u> growing in detritus or on fine sand. Each sample was then placed in a labelled polythene bag without water. Although a sampler for flowing weed was devised during the preliminary stage of the programme this was not used as it did not sample the underlying substratum also, and it was felt that use of the flowing weed sampler would disturb the underlying substratum too much for a meaningful Surber sample to be taken afterwards. When a sample of flowing weed had to be taken, a Surber sampler was used to obtain both the unrooted weed and the underlying substratum as a single unit. The 25 samples taken from a given site in the morning were processed as far as possible the same afternoon. Any samples in which the macrophytes had not been frozen or the invertebrates preserved were held overnight in a cold room to reduce the possibility of decay or predation.

On the 4 occasions when samples of the substratum were taken from within the 50 samples, the cores were obtained as soon as the Surber or box sampler had been positioned in the river. An $0.001 m^2$ core was taken in conjunction with the box sampler and an $0.007 m^2$ core taken from within the Surber sampler.

If the 40-mesh component contained very large numbers of animals on initial inspection it was subsampled before the invertebrates were once again removed, identified and counted. This procedure was carried out separately for each of the 5 samples in the 5 habitat types in both sampling sites. Size frequency data was then collected on all species or groups of species, with the exception of oligochaetes, triclads, chironomids and some other groups of diptera, by measuring up to 100 animals per group of 5 samples in each of the 10 habitat types. Thus, data obtained on the size structure of the *Gammarus pulex* population on *Ranunculus* in the shaded site is available for each month and can be compared with similar data obtained for each of the other 9 habitat types. The 10-mesh and 40-mesh invertebrate components of the sample, which had been counted and in most cases measured were dried in an oven at 60 C and weighed to obtain data on the biomass of each sample. The chironomids were counted and weighed separately as many species were involved and this sampling programme only obtained the larger instars. Since many of the oligochaetes undergo fission and others were damaged during the processing of samples, they were also weighed separately, but without being either measured or counted.

In the bulking procedure, which was used for eight months of the year, each of the 5 samples from a given habitat type was divided into the 40 and 10-mesh components. Each 10-mesh component was then subsampled to the same degree (normally to 0.2$ of the original sample) before all 5 subsamples were put together to give a single sample equivalent in volume to approximately 1.25 normal samples. From July 1971 onwards a Tyler sample splitter was used in all subsampling, but prior to the acquisition of this equipment subsampling was carried out by spreading the sample evenly over a sieve and removing quadrants at random. Exactly the same procedure was adopted for the 40-mesh components, except that they were frequently subsampled to a higher degree (i.e. 0.125 or even 0.0625 of each sample) due to the abundance of small invertebrates. Thus a sample consisting of separate 10 and 40-mesh components was obtained from the original 5 samples. This was sorted and the animals identified, counted and size frequency data collected. Finally, dry weight data was obtained as before and the appropriate calculations carried out so that comparisons between biomass, numerical and size frequency data could be made with non-bulked months.

A flow diagram illustrating the monthly sequence of processes involved in the macrophyte and invertebrate programme is given in Figure 6.

3.1.5. Laboratory Procedures for Macrophyte Samples

The 30 macrophyte samples obtained each month were sorted and weighed individually. Initial separation of the macrophytes from the substratum was achieved by flotation, and by repeated washings almost all animals were removed from the weed. Samples were then placed in separate polythene bags and frozen until the more pressing work of removing and preserving the invertebrate component of all the samples was complete. After thawing, each macrophyte sample was carefully examined and any invertebrates such as Simulium pupae were removed and placed in the appropriate sample. Many samples contained more than one species of macrophyte and, where this occurred, the minor species in the weed sample was separated from the major component before all were dried in an oven at 60°C and weighed individually. Macrophyte samples taken for the months of March, June, September and December 1971 were ground up and have been stored for calorific determination at a later date.

There is some evidence of a decrease in dry weight of macrophyte due to loss of soluble components in the macrophyte tissue as a result of thawing following the freezing procedure. In addition, losses may occur when macrophytes are transported back to the laboratory in polythene bags which also contain gravel. Appropriate correction factors will be applied as required.

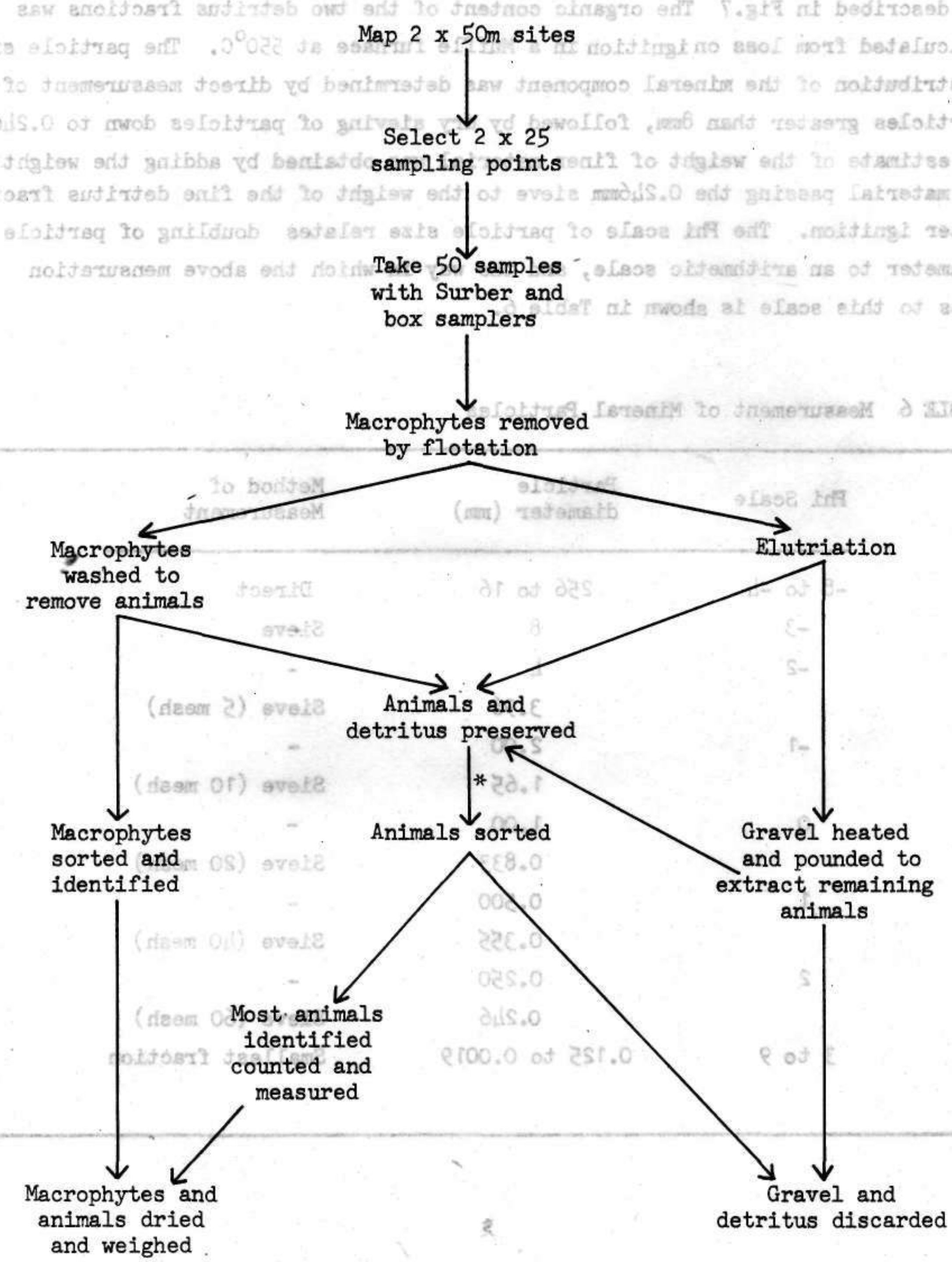
3.1.6. Laboratory Procedures of Invertebrate Samples

After the removal of macrophytes by flotation, most of the invertebrates were separated from the mineral fraction of the substrate by elutriation. Large cased-caddis were hand picked from the remaining mineral fraction after it had passed through a 5-mesh sieve and the smaller cased caddis (e.g. Agapetus sp.) which slip through the mesh were removed by hot water treatment as outlined previously. Each sample was then preserved separately in a polythene bag containing 5% formalin.

The handling procedure then followed one of two courses. In four months of the year (March, June, September and December 1971) each sample was processed individually so that a mean figure and variance could be obtained for both the total dry weight biomass and number of organisms in the different species for each habitat type. In the remaining eight months of the year the procedure was shortened by bulking and subsampling the 5 samples from a given habitat type. This means that comparable data on mean figures for biomass and numbers of invertebrates are still available but without the accompanying information on variance.

In the non-bulking procedure the preserved sample was first separated into two components using a pair of 10 and 40-mesh sieves. Any animals capable of passing through the 40-mesh sieve were not considered. All animals in the 10-mesh component were removed, identified as far as possible and counted.

Fig 6. Flow Diagram showing the Procedure for Studying Macrophytes and Invertebrates at Bagnor.



* Sub-sampling may take place at this point

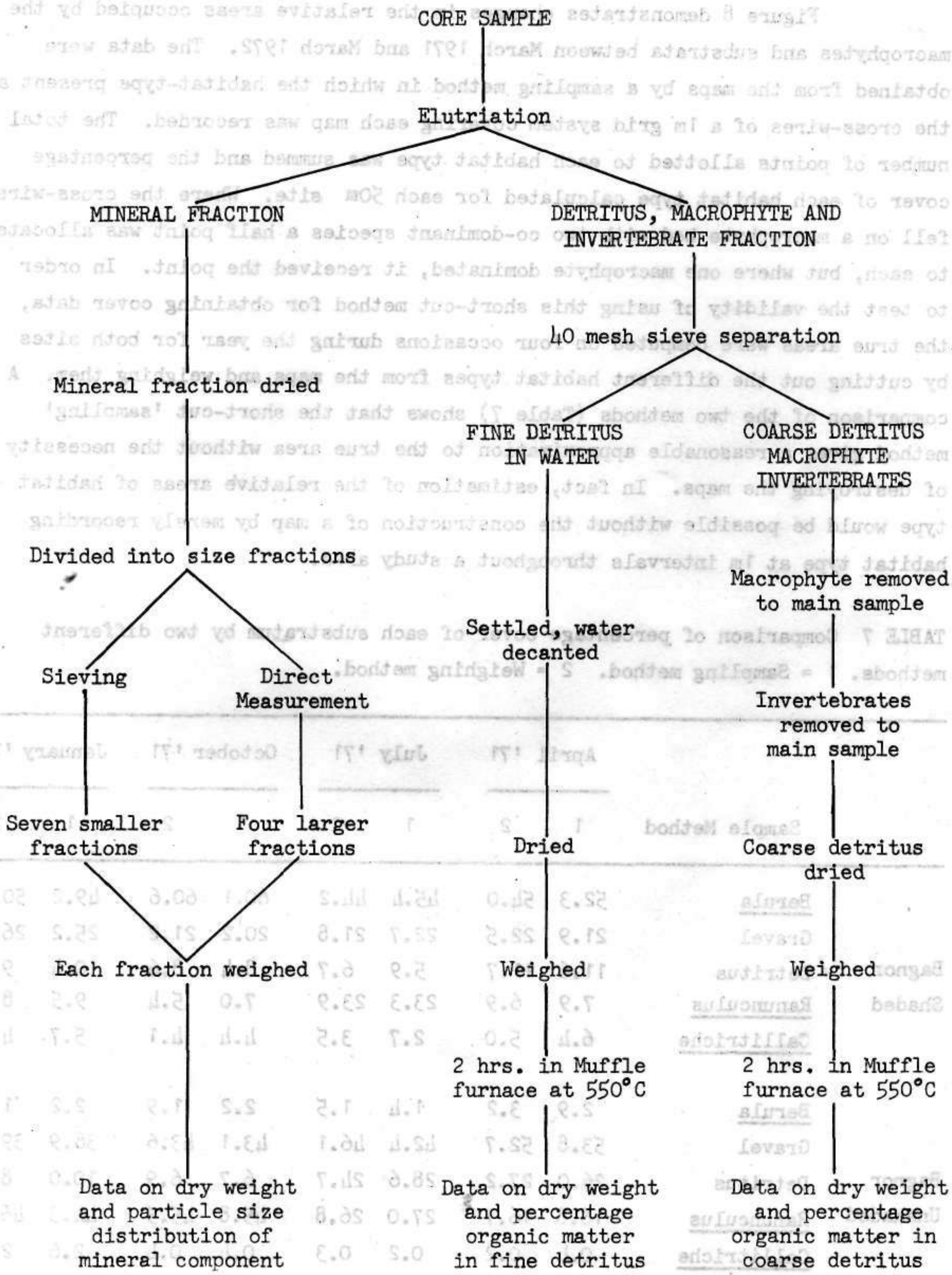
3.1.7. Laboratory procedures for Analysis of the Substrata

A sample of substratum was removed from within each of the 50 samples taken in March, June, September and December 1971, using the 0.001 and 0.007m² corers described in Section 2.3.5. The procedure for the analysis of each core is described in Fig.7 The organic content of the two detritus fractions was calculated from loss on ignition in a Muffle furnace at 550°C. The particle size distribution of the mineral component was determined by direct measurement of particles greater than 8mm, followed by dry sieving of particles down to 0.246mm. An estimate of the weight of finer material was obtained by adding the weight of material passing the 0.246mm sieve to the weight of the fine detritus fraction after ignition. The Phi scale of particle size relates doubling of particle diameter to an arithmetic scale, and the way in which the above mensuration fits to this scale is shown in Table 6.

TABLE 6 Measurement of Mineral Particles

Phi Scale	Particle diameter (mm)	Method of Measurement
-8 to -4	256 to 16	Direct
-3	8	Sieve
-2	4	-
	3.96	Sieve (5 mesh)
-1	2.00	-
	1.65	Sieve (10 mesh)
0	1.00	-
	0.833	Sieve (20 mesh)
1	0.500	-
	0.355	Sieve (40 mesh)
2	0.250	-
	0.246	Sieve (60 mesh)
3 to 9	0.125 to 0.0019	Smallest fraction

Fig 7. Laboratory Procedure for Core Samples



3.2. RESULTS

3.2.1. The Macrophyte Programme

Figure 8 demonstrates changes in the relative areas occupied by the macrophytes and substrata between March 1971 and March 1972. The data were obtained from the maps by a sampling method in which the habitat-type present at the cross-wires of a 1m grid system covering each map was recorded. The total number of points allotted to each habitat type was summed and the percentage cover of each habitat type calculated for each 50m site. Where the cross-wires fell on a macrophyte bed with two co-dominant species a half point was allocated to each, but where one macrophyte dominated, it received the point. In order to test the validity of using this short-cut method for obtaining cover data, the true areas were computed on four occasions during the year for both sites by cutting out the different habitat types from the maps and weighing them. A comparison of the two methods (Table 7) shows that the short-cut 'sampling' method gives a reasonable approximation to the true area without the necessity of destroying the maps. In fact, estimation of the relative areas of habitat type would be possible without the construction of a map by merely recording habitat type at 1m intervals throughout a study area.

TABLE 7 Comparison of percentage cover of each substratum by two different methods. 1 = Sampling method. 2 = Weighing method.

		April '71		July '71		October '71		January '72	
	Sample Method	1	2	1	2	1	2	1	2
Bagnor Shaded	*Berula*	52.3	54.0	45.4	44.2	60.1	60.6	49.2	50.9
	Gravel	21.9	22.5	22.7	21.8	20.2	21.2	25.2	26.5
	Detritus	11.6	11.7	5.9	6.7	8.4	8.6	10.4	9.9
	Ranunculus	7.9	6.9	23.3	23.9	7.0	5.4	9.5	8.1
	Callitriche	6.4	5.0	2.7	3.5	4.4	4.1	5.7	4.6
Bagnor Unshaded	*Berula*	2.9	3.2	1.U	1.5	2.2	1.9	2.2	1.9
	Gravel	53.8	52.7	42.4	46.1	43.1	43.6	38.9	39.1
	Detritus	26.0	27.2	28.6	24.7	6.7	6.9	10.0	8.9
	Ranunculus	16.8	16.7	27.0	26.8	45.8	45.5	44.3	46.2
	Callitriche	0.4	0.2	0.2	0.3	0.4	0.4	2.6	2.3
	Zannichellia	0.0	0.0	0.4	0.6	1.8	1.7	2.2	1.7

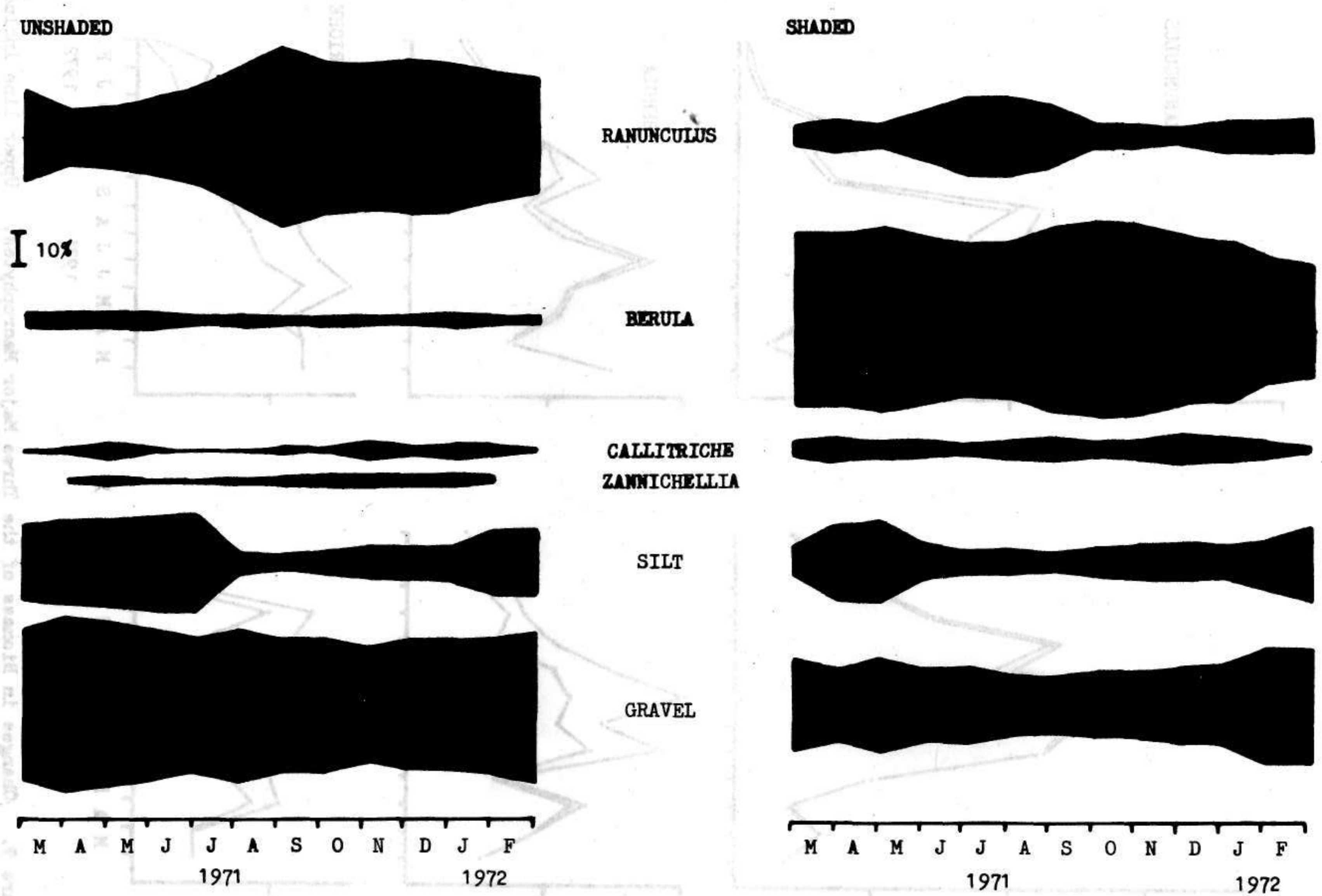


Figure 8. Seasonal Changes in the Relative Areas of Substrata on the Shaded and Unshaded Sites. March 1971 to March 1972.

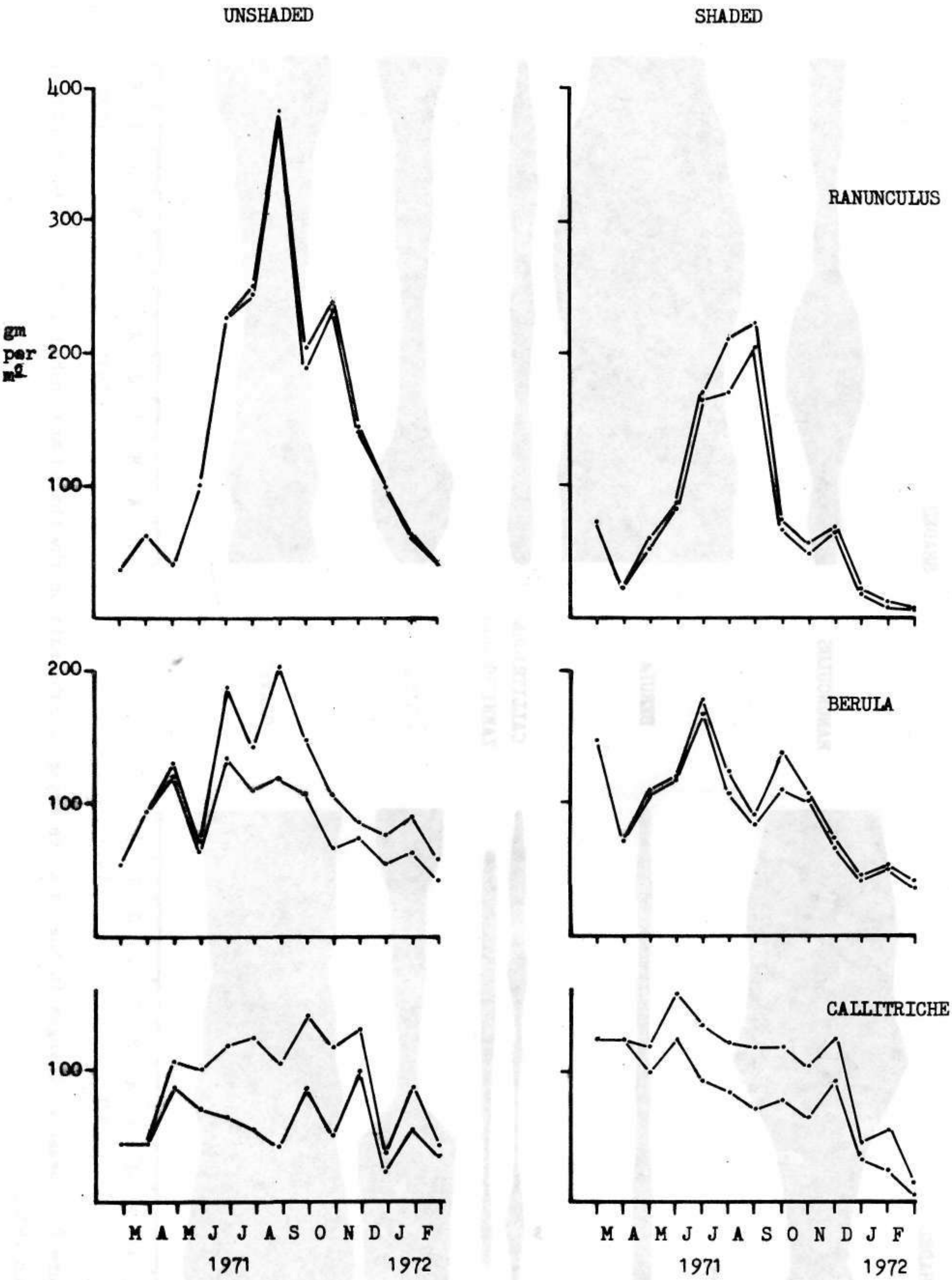


Figure 9. Changes in Biomass of the Three Major Macrophytes. Upper line includes **other species of macrophyte growing with the named species.**

Changes in standing biomass of macrophyte per m^2 during the year (calculated from the arithmetic mean of five $0.05m^2$ samples) are presented in Figure 9. The upper line in each graph shows the mean biomass of macrophyte including species of macrophyte other than that for which the sample was taken, but which occurred due to the impurity of the macrophyte bed. The lower line gives the mean biomass of pure macrophyte. Note that on the unshaded site Ranunculus (the dominant macrophyte) was almost pure, as was the dominant macrophyte Berula on the shaded site. In addition, the Ranunculus on the shaded site was almost pure, but Berula on the unshaded site tended to occur with Ranunculus. Callitriche was normally impure and since it occupied a small area in our two sites (Fig. 8) it sometimes became necessary to take samples in which other macrophytes were slightly dominant in order to obtain any data.

A major weed cut occurred after the September sampling and it is clear that Ranunculus was the species most drastically affected.

Using the data in Figures 8 and 9 it is possible to estimate changes in the total biomass of macrophyte for each site through the year but this analysis will not be made until the correction factors for the dry weight data have been applied. Macrophyte removed during the September cut was collected using stop nets and the estimated biomass will be used to assess the proportion of the total standing biomass removed by the cut. A limited number of samples of Zannichellia palustris (Fig. 8) have been taken on the unshaded site to provide basic information on the importance of this macrophyte to the invertebrate fauna.

The twelve month series of maps for both sampling sites are now being examined in order to understand the dynamics of weed bed movement, growth and decay through the seasons. As an example, there is a tendency for an area which is gravel one year to be colonised by Berula the following year and vice versa on the shaded site (Fig. 10).

This work has provided the baseline for an understanding of the dynamics of Ranunculus and Berula but it is clear that in the coming year a further site will be required in which Callitriche can be studied in greater detail. Further analysis of the biomass data for Ranunculus and Berula has made possible an estimate of the number of samples required during the next twelve months for an increased precision of biomass estimation in these two species. Studies are also planned to assess the importance of decaying macrophyte as a food source for invertebrates. Finally, a general macrophyte survey of the Lambourn will be carried out so that the data on growth and decay of Ranunculus, Berula and Callitriche can be seen in the context of the river as a whole.

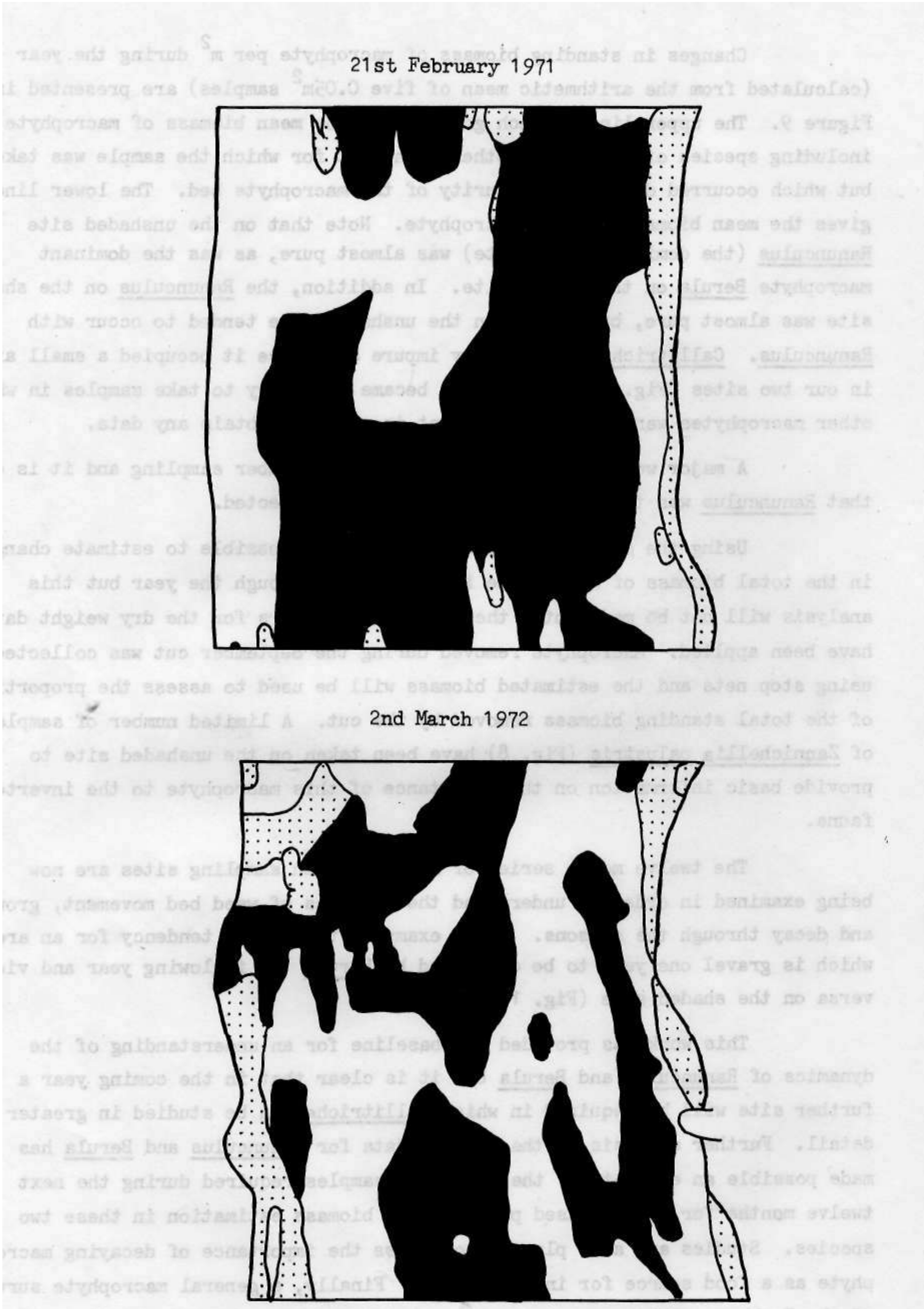


Figure 10. Changes in the Position of <u>Berula</u> in a 10m. Section of the Shaded Site over a One-year Period. Black = <u>Berula</u>, White = Gravel, Stipple = Other substrata.

3.2.2. The Invertebrates.

Unlike the macrophyte programme, it has not been possible to process all invertebrate samples in the month following their collection due to the very time consuming processes of picking, identifying and counting the wide diversity of invertebrates encountered. At present the total list of invertebrate species recorded for the Lambourn and Winterbourne stands at approximately 280 species. Over half the samples have been processed to date but only examples of the type of data being collected will be presented in the following section.

On a non-bulking month the following results are becoming available:

1. Total biomass of invertebrates in each of 50 samples (in addition the oligochaetes are weighed separately, since many small and disintegrating specimens are encountered which cannot be counted satisfactorily. From June 1971 onwards the chironomids have also been weighed separately, for although they are counted and identified as far as is feasible in the time available, the complex of species present and the absence of early instars would make size frequency data meaningless).

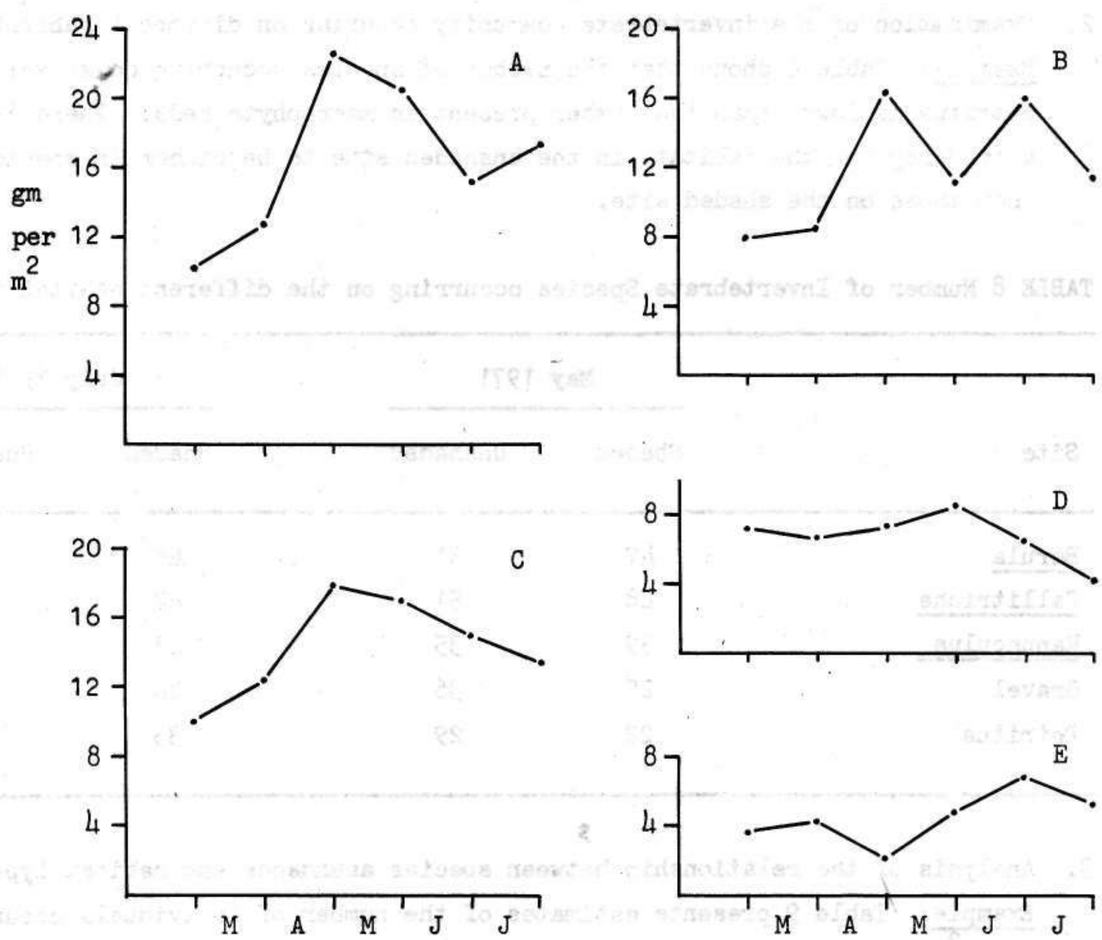


Figure 11. Changes in the Mean Biomass of Invertebrates from the Five Substrata, March - August 1971. A = <u>Berula</u>, B = <u>Ranunculus</u>, C = <u>Callitriche</u>, D = Gravel, E = Detritus.

2. Number and identity of animals in each of $0 samples.
3. Size frequency data for most invertebrate species represented in each of 10 different habitat types.

On a bulking month the following results are becoming available:-

1. Mean biomass of invertebrates per sample in each of 10 habitat types.
2. Mean number and identity of invertebrates per sample in each of 10 habitat types.
3. Size frequency data for most invertebrate species represented in each of 10 different habitats.

The following analyses will therefore be possible:-

1. Comparison of the standing biomass of invertebrates in 10 different habitats from month to month.
   Example: Figure 11 documents the changes in biomass of invertebrates on 5 habitat types over a period of 6 months (data for the shaded and unshaded sites amalgamated). Note the low biomass on gravel and detritus as compared to the macrophytes and the fact that the latter three habitat types all have a peak biomass at the beginning of May.
2. Examination of the invertebrate community occuring on different habitat types.
   Example: Table 8 shows that the number of species occurring on gravel and detritus is lower than the number present in macrophyte beds. There is also a tendency for the habitats in the unshaded site to be richer in species than those on the shaded site.

TABLE 8 Number of Invertebrate Species occurring on the different habitat types.

	May 1971		July 1971	
Site	**Shaded**	**Unshaded**	**Shaded**	**Unshaded**
Berula	47	51	46	51
Callitriche	48	51	42	47
Ranunculus	39	35	43	50
Gravel	25	36	24	34
Detritus	22	29	33	27

3. Analysis of the relationship between species abundance and habitat type.
   Example: Table 9 presents estimates of the number of individuals occurring per m^2 for several important species or groups in relation to habitat type in June 1971. Ephemera danica, Agapetus sp. and Ephemerella ignita all occurred in greater abundance in the substratum under Berula, on gravel and in Callitriche respectively on both sites. In contrast Gammarus pulex was

invariably more abundant in each of the shaded site habitats, whilst chironomid numbers reached their highest numbers in the unshaded site.

TABLE 9 Distribution of Selected Invertebrates in Relation to Habitat Type - June 1971

		Gravel	Detritus	Berula	Callitriche	Ranunculus
Ephemera danica	Shaded	132	24	1,280	488	276
	Unshaded	200	692	1,292	584	744
Gammarus pulex	Shaded	1,912	740	10,188	6,780	2,528
	Unshaded	1,872	180	1,512	3,912	1,568
Agapetus sp.	Shaded	1.396	-	36	60	560
	Unshaded	1,560	4	16	140	240
Ephemerella ignita	Shaded	28	36	2,064	6,028	576
	Unshaded	444	52	1,172	3,100	1,624
Chironomidae	Shaded	392	1,352	1,612	4,968	4,884
	Unshaded	5,636	6,928	24,672	18,152	19,844

4. Analysis of the life history of a wide variety of invertebrates and estimation of production for a more restricted group for which very detailed information is available. The latter will include such important species as Ephemera danica, Gammarus pulex, Agapetus etc.

Some important invertebrates are inadequately sampled by the programme outlined previously. It has, therefore, been necessary to carry out some supplementary studies in order to obtain information on a) the life history of Agapetus, b) the number of generations per season in the Simuliidae and c) weekly changes in species composition of the Chironomidae. Further important invertebrate groups will be examined in greater detail during the second half of the project.

Weekly samples of Agapetus have provided substantial evidence that only a single generation of this abundant caddis occurs in the Lambourn during the summer (Fig. 12).

The Simuliidae, which feed by filtering suspended matter and therefore depend upon a flow of water may prove sensitive to a change in flow regime. An attempt has, therefore, been made to determine the number of generations which the various species of Simulium complete during the year by

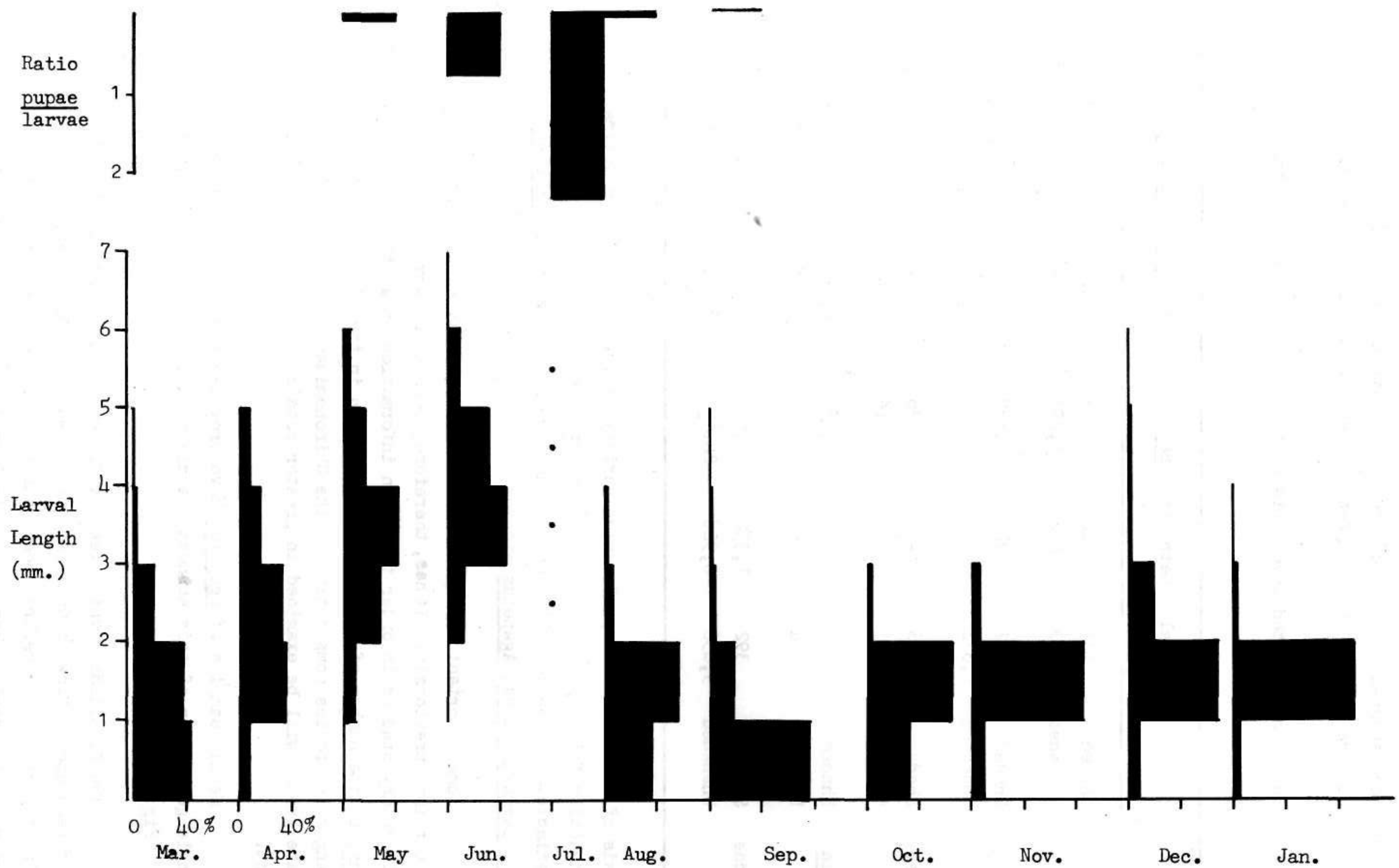


Figure 12. Histogram showing the Growth of <u>Agapetus</u> larvae and the Ratio of Pupae to Larvae at Bagnor, March 1971 to January 1972. ● = Insufficient animals.

the weekly monitoring of changes in the density of pupae. Most of the first 12 months samples have been analysed and the method appears to be yielding useful results. Much work remains to be done on the Chironomidae, which form a significant source of food for fish in the Lambourn. The collections made during this first year are being used to identify and determine the life histories of the major species. Finally, a species list supported by a reference collection is being built up and to date approximately 280 species have been recorded. Table 10 gives a general breakdown of this species list, which includes both Lambourn and Winterbourne invertebrates. A limited amount of rearing out of insects is contemplated in the near future in order to identify some of the more difficult groups to species.

TABLE 10 Macroinvertebrate fauna of the Lambourn and Winterbourne

			Approx. No. Species
Platyhelminthes -	Turbellaria		6
Annelida -	Oligochaeta		15
	Hirudinea		7
Mollusca			20
Arthropoda -	Crustacea		6
	Insecta -	Hymenoptera	1
		Megaloptera	1
		Plecoptera	3
		Hemiptera	12
		Coleoptera	40
		Ephemeroptera	14
		Trichoptera	44
		Diptera	110
			279

This list excludes the following groups, which although present, are not being examined in detail as yet: Coelenterata; Hydracarina; Ostracoda; Microcrustacea; Nematoda.

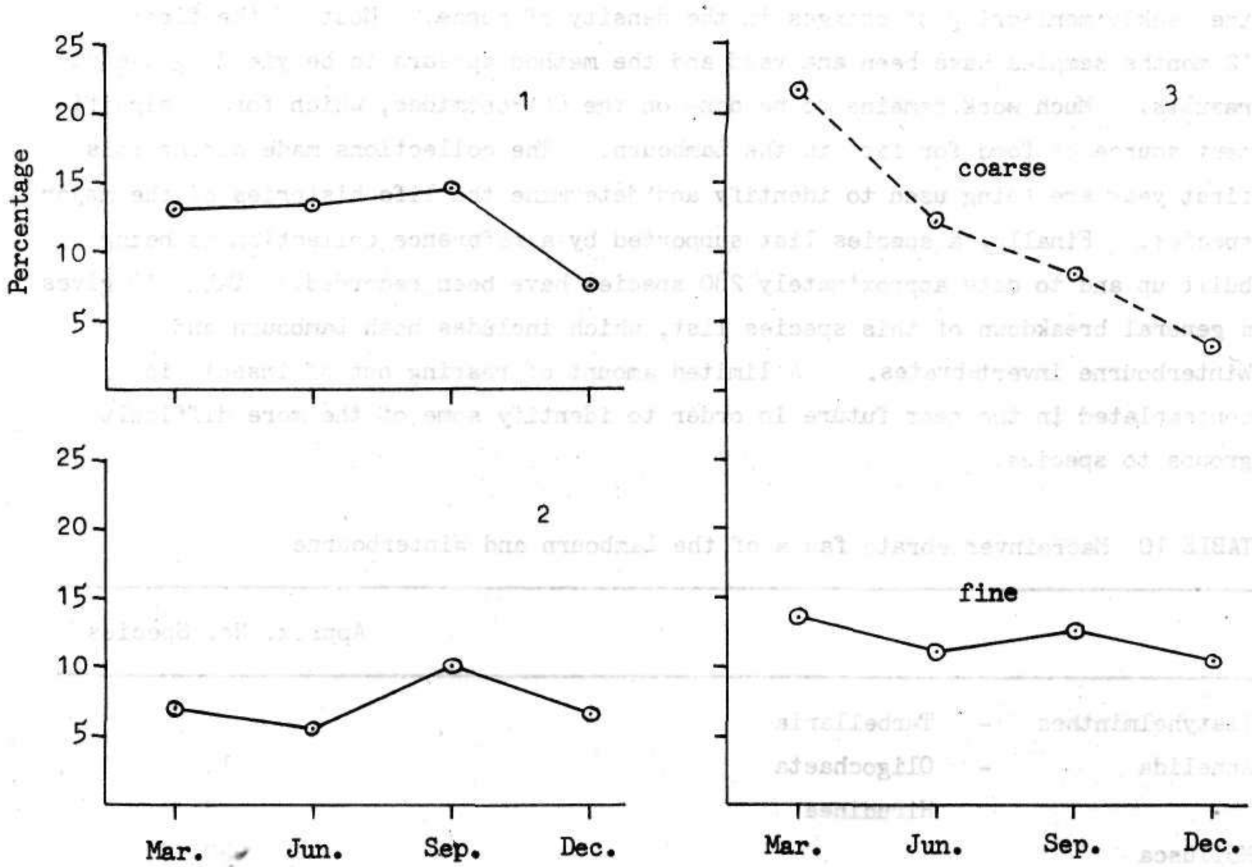


Figure 13. Changes in the Percentage Composition of the Substrata during 1971, expressed as means of 50 Samples. (1) $\frac{\textbf{Detritus}}{\textbf{Total Substratum}}$ (2) $\frac{\textbf{Coarse Detritus}}{\textbf{Total Detritus}}$
(3) Organic Content of the Coarse and Fine Detritus Fractions.

3.2.3. Analysis of Substrata

The following data is available for each of the 50 samples taken at three monthly intervals during 1971.

1. The proportion of detritus to mineral.
2. The proportion of detritus larger than 0.355mm to the total detritus fraction.
3. The organic content of the coarse (0.355mm.) and fine detritus fractions.

Variation in the mean figures obtained from 50 samples with time of year are shown for analyses 1-3 in Figure 13.

4. The size distribution of mineral particles expressed on the Phi scale. (The 26 $0.001m^2$ cores in March and the 24 in June were not treated in this way.)

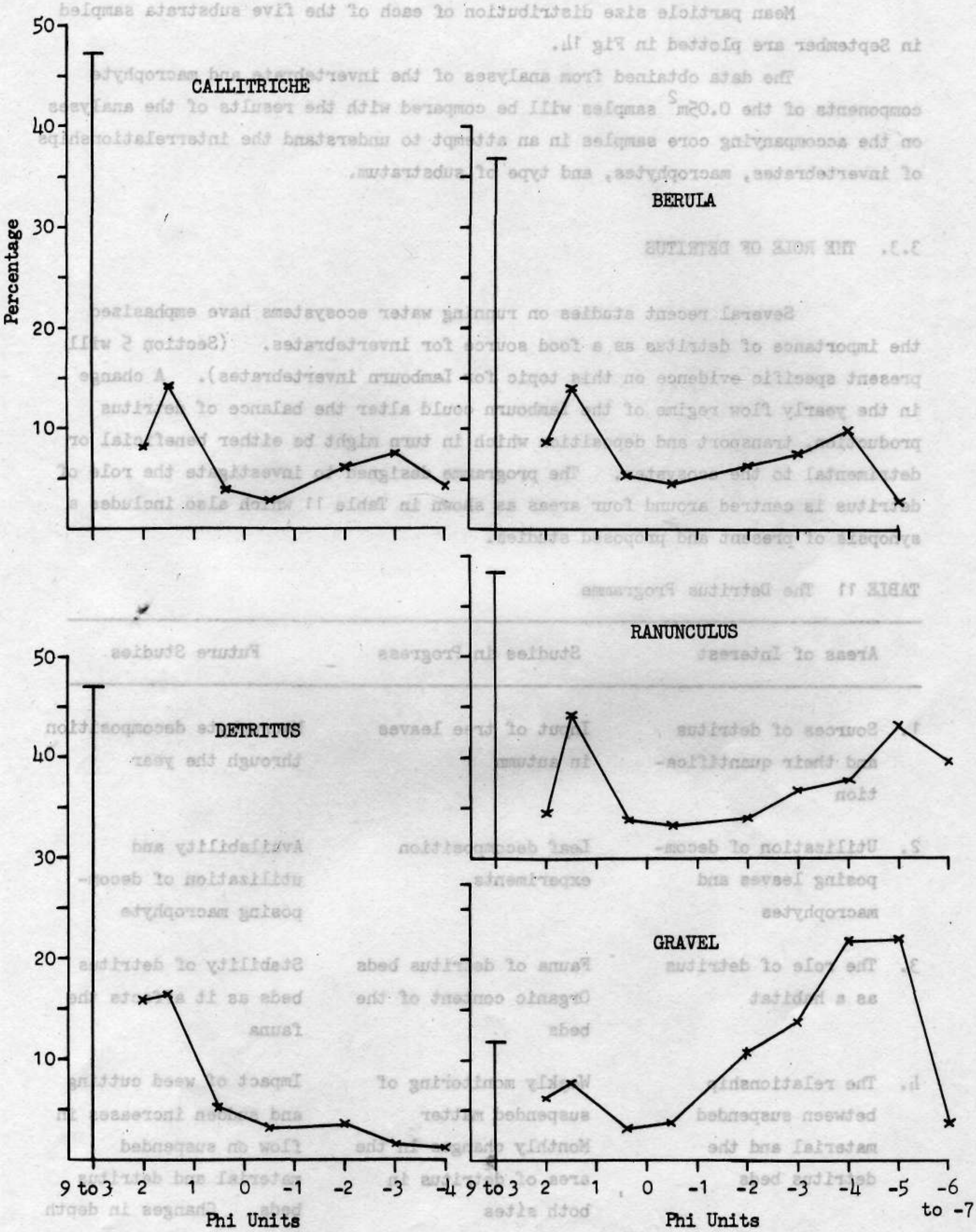


Figure 14. Mineral Size Fractions expressed as Percentage of the Total Material for each of the Five Substrata, September 1971.

Mean particle size distribution of each of the five substrata sampled in September are plotted in Fig 14.

The data obtained from analyses of the invertebrate and macrophyte components of the 0.05m² samples will be compared with the results of the analyses on the accompanying core samples in an attempt to understand the interrelationships of invertebrates, macrophytes, and type of substratum.

3.3. THE ROLE OF DETRITUS

Several recent studies on running water ecosystems have emphasized the importance of detritus as a food source for invertebrates. (Section 5 will present specific evidence on this topic for Lambourn invertebrates). A change in the yearly flow regime of the Lambourn could alter the balance of detritus production, transport and deposition which in turn might be either beneficial or detrimental to the ecosystem. The programme designed to investigate the role of detritus is centred around four areas as shown in Table 11 which also includes a synopsis of present and proposed studies.

TABLE 11 The Detritus Programme

Areas of Interest	Studies in Progress	Future Studies
1. Sources of detritus and their quantification	Input of tree leaves in autumn	Macrophyte decomposition through the year
2. Utilization of decomposing leaves and macrophytes	Leaf decomposition experiments	Availability and utilization of decomposing macrophyte
3. The role of detritus as a habitat	Fauna of detritus beds Organic content of the beds	Stability of detritus beds as it affects the fauna
4. The relationship between suspended material and the detritus beds	Weekly monitoring of suspended matter Monthly changes in the area of detritus in both sites	Impact of weed cutting and sudden increases in flow on suspended material and detritus beds Changes in depth of detritus in both sites

Leaf fall and macrophyte decomposition are thought to be the most important sources of detritus in the Lambourn. Between the beginning of October 1971 and February 1972 each of the 50 samples taken monthly had all tree leaves removed, identified and weighed in order to document the occurence of this potential food resource in the two study areas. Willow and alder leaves occured most commonly and an estimated peak dry weight of 16.4kgm. of leaves was recorded at the begining of November 1971 for the 100m. of river under study. If the leaves were evenly spread over this section of river each m^2 would have approximately 20 gm. dry weight (60 gm. wet weight) which could be represented by 100 whole leaves. These figures only include whole or partially eaten leaves where 50% or more of the leaf was present. The decrease in weight of leaves in the study area during the winter could be a result of both utilization of this food resource by invertebrates and also due to washing downstream of leaves caught by the increased winter flow.

Experiments designed to assess the rate of utilization of decomposing leaves have already been started and similar work is contemplated on the macrophytes next year. Known weights of fresh alder and willow leaves were placed in bags of three different mesh sizes ranging from a fine mesh (0.27mm.) which prevented the entry of invertebrates to a medium (3.0mm.) and coarse mesh (16 x 4mm.)where the leaves were more accessible to invertebrate attack. Groups of bags containing leaves were placed in two areas where leaves normally accumulate, namely in a detritus bed and at the downstream end of a macrophyte bed. Since the end of November 1971 when the experiment was started, groups of bags have been raised periodically to assess the change in dry weight of leaves and examine the accompanying invertebrate fauna in the medium and coarse mesh bags. Once removed, a bag cannot be replaced since the leaves are required for dry weight data and hence the time sequence of decomposition must be obtained by raising a series of bags at different time intervals. At present data is available for the first 15 weeks and the remaining group of bags will be removed after a total of 25 weeks in the river. Fig 15 shows the change in weight of the willow and alder leaves which were placed in the macrophyte bed. The initial increase in weight recorded in the fine mesh bags may be a result of colonisation by bacteria, fungi and protozoa before decomposition of the leaf tissue by these organisms set in. Note the more rapid breakdown of the alder leaves. Data for the coarse and medium mesh bags has been amalgamated since both were attacked by invertebrates. It is debatable whether the invertebrates which attack decomposing leaves are primarily obtaining energy from the leaf tissue itself or from its accompanying microorganisms. The two lower graphs illustrate the more rapid loss of leaf tissue when both microorganisms and invertebrates are breaking it down and also the fact that alder is prefered to willow.

The role of detritus as a habitat has already been touched upon briefly

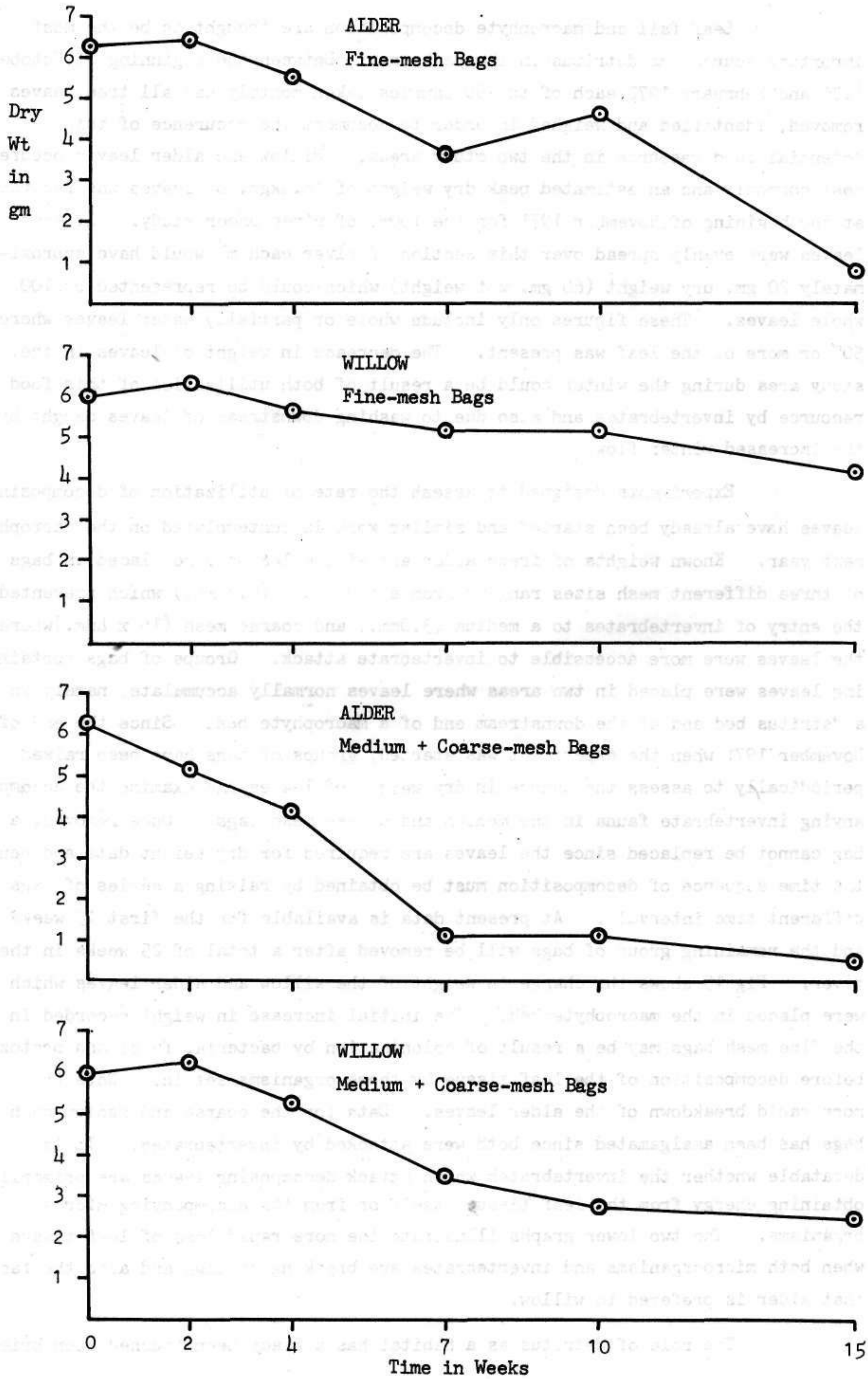


Figure 15. Breakdown of Alder and Willow leaves in a Macrophyte Bed.

In Section 3.2.2. it was shown that detritus has a relatively low species diversity and standing biomass of invertebrates whilst in Section 3.2.3. some data on the organic content of detritus beds was presented. Further work will attempt to assess whether instability of detritus beds limits the exploitation of what appears to be a large source of energy.

Finally work is in progress to understand the interrelations of suspended material and deposited detritus. Weekly samples of water have been taken in both the Lambourn and Winterbourne at Bagnor since June 1971. Three 2 litre replicates are filtered through glass fibre filter paper which retains all particles above 2μ. Mean dry weights of suspended matter per litre are obtained and an estimate of the percentage organic matter is calculated from loss on ignition at 540°C in a Muffle furnace. Fig. 16 graphs the total suspended material per litre against the percentage inorganic in the Winterbourne for the period June 1971 to

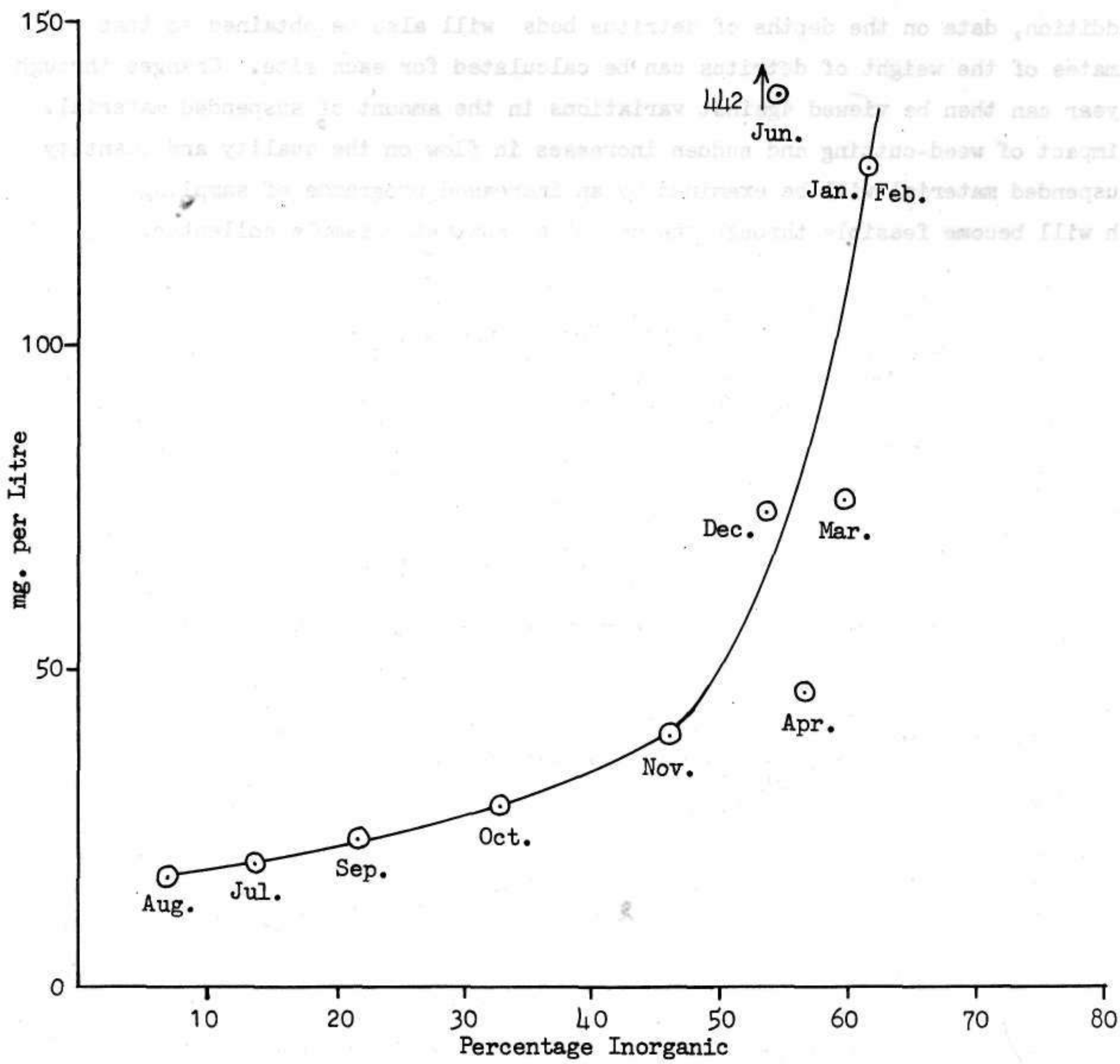


Figure 16. Variation in the Quantity and Quality of Suspended Material in the Winterbourne, June 1971 - March 1972.

March 1972. Mean monthly figures were calculated using the data collected each week. It is clear that as the total amount of material in suspension increases, there is an initial rapid increase in the proportion of inorganic material, which later slows down as an apparent upper limit is reached. In general, the amount of material in suspension is low in summer and high in winter, but as a consequence of very high rainfall and increased flow in June 1971, the highest levels of suspended material were recorded in that month in the Winterbourne. Similar data are available for the Lambourn except that levels of suspended material lower than 30 mg. per litre with an inorganic content of 34% have not been recorded. It is hoped that a relationship between total weight of suspended material and a physical parameter such as flow or rainfall will become apparent when the appropriate data are examined.

Monthly changes in the area of detritus on both sites have been monitored for the past 12 months and this data will continue to be collected. In addition, data on the depths of detritus beds will also be obtained so that estimates of the weight of detritus can be calculated for each site. Changes through the year can then be viewed against variations in the amount of suspended material. The impact of weed-cutting and sudden increases in flow on the quality and quantity of suspended material will be examined by an increased programme of sampling which will become feasible through the use of an automatic sample collector.

4. THE DISTRIBUTION OF INVERTEBRATES IN THE WINTERBOURNE STREAM

4.1. INTRODUCTION AND AIMS

A limited amount of sampling for invertebrates was carried out in the Winterbourne Stream during the first three months of the project and in May and August 1971. However, it was decided to leave the major part of the study until 1972, after the completion of the main Lambourn invertebrate sampling programme. Preliminary test sampling was undertaken in January 1972 so that a one-year programme could be started in February.

The aim of the sampling programme is to collect data on the invertebrate fauna so that an assessment can be made of the impact of drought conditions, whether naturally occurring or induced by pumping. There is evidence to suggest that winterbournes may be significant trout spawning areas and if drought conditions cause the periodic elimination of many invertebrates which form an important food source for the trout, then it is likely that trout production in the bourne will decrease. The first objective is, therefore, the collection of data on the distribution of the invertebrates so that if drought conditions occur their effect on distribution can be assessed and recolonisation documented.

4.2. PRELIMINARY TEST SAMPLING

It was decided to sample 25m sections of stream at appoximately 0.5km intervals throughout the Winterbourne stream. Twenty five metres was sufficient to include all of the habitat types characteristic of a given section and by sampling at 0.5km intervals a total of about 16 sites were involved. Test sampling was carried out on a 25m section above the gauging weir at Bagnor where invertebrate species diversity was greatest.

It was considered necessary to record habitat types occurring in the 25m section since these could influence species composition. A simplified mapping procedure was therefore developed which occupied approximately one man-hour in the field per 25m section and from this it was possible to compute the relative areas occupied by the different habitat types.

Since species distribution of the invertebrates took precedence over the determination of species abundance in a few common species, qualitative collection methods were examined. Each member in the team of four sampled all habitats within the 25m section for five minutes using a pond net. In the laboratory the material was carefully examined and after a period of two hours the graphs of species acquisition against time levelled off, indicating that further searching would be unprofitable. The four species lists were then compared to assess the total number of species and the number of occurrences of each species out of a total of four. (Table 12)

TABLE 12. The Number of Species and their Frequency of Occurrence in Four Qualitative Samples. Collections were standardized by pond-netting for 5 minutes.

	Number of Occurrences				
	4	3	2	1	Total
Number of Species	28	18	21	27	94

This process was repeated for another set of four five-minute collections and 21 new species were acquired, making a grand total of 11 5 species. However, of the new species, only two were recorded by three people, five by two people and fourteen by a single person. Therefore it was concluded that in general all common species were collected in the first five minutes and that additions after this time were uncommon species which would be of little significance as trout food.

Field trials using quantitative sampling equipment were also carried out to assess the feasibility of determining invertebrate distribution and abundance simultaneously. A Surber or box sampler taking an 0.05m portion of stream bed was considered too large for quantitative sampling in a small stream like the Winterbourne, with its rapidly changing habitat types, so two smaller samplers were tested. The first was a Surber sampler having a quadrat area of $0.0196m^2$ which was used on sand and gravel. The second, a Maitland corer which sampled an area of $0.0035m^2$, was intended for use on detritus but was also used on macrophyte over detritus. One Surber therefore covered an area equivalent to 5.6 Maitland core samples. In testing these samplers, initial assessment was based upon field sampling time and the rate of species acquisition as more samples were taken. Collection of 25 Surber samples on sand and gravel took one and a half man-hours and after qualitative examination in the laboratory 44 species were recorded. Figure 17 shows a graph of species acquisition after 5, 10, 17 and all 25 samples had been examined. It was only possible to take 75 Maitland cores in two man-hours, and these yielded 73 species (Fig. 17). These Maitland cores represented a total area of $0.26m^2$, compared with the $0.49m^2$ sampled by 25 Surber samples. Thus about four man-hours would be necessary to sample an area of macrophyte equivalent to the area of gravel sampled in one and a half man-hours. The total number of species recorded by the 25 Surber and 75 Maitland samples came to 83. Rate of species acquisition (Fig. 17) was so low after this intensity of sampling that many more samples would be required to reach the number of species recorded by a five minute qualitative collection by the team (*9k* species). It was concluded that timed qualitative sampling was the more efficient and less time consuming method of obtaining the required data on distribution. The

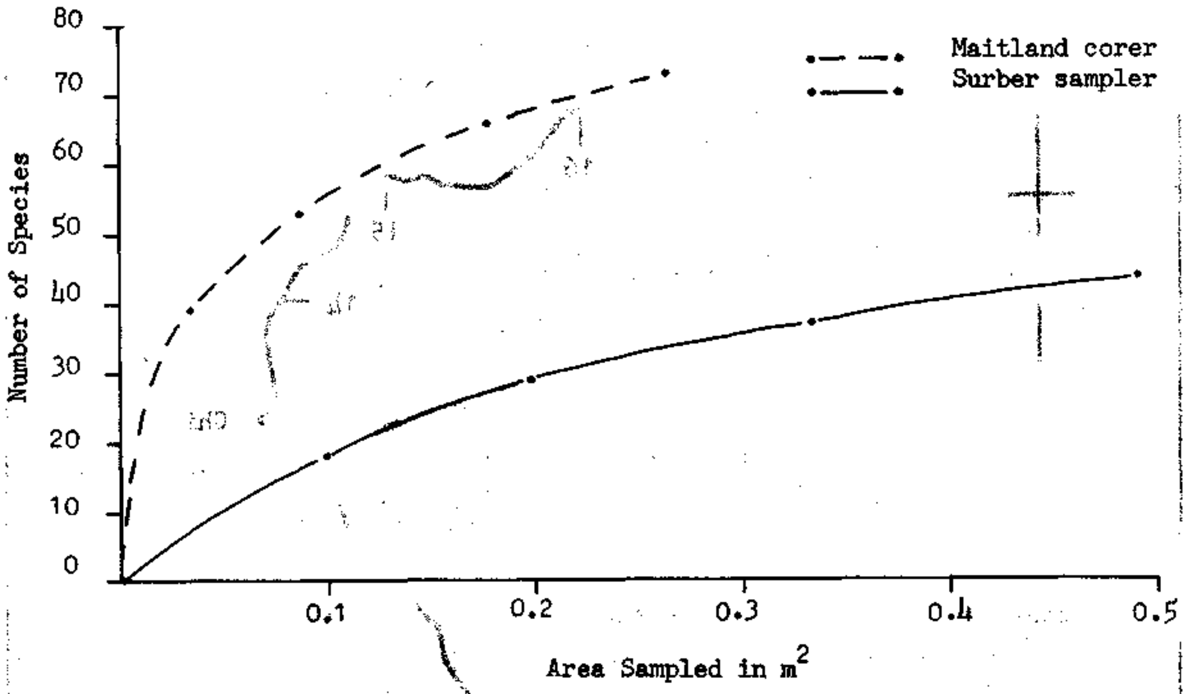


Fig. 17 Species acquisition by Maitland cores and Surber samples

procedure of analysing each collection separately also gave an index of frequency of occurrence for each species on a 1 - 4 scale. Quantitative sampling of invertebrates which were important food organisms of trout could be carried out on major habitat types at selected sites as required.

4.3. SAMPLING PROGRAMME FOR 1972

Twelve of the sampling stations (Fig. 18) are 25m sections of stream. The other four stations (10, 12, 14 and 16) are ponds which are treated as individual sites. Parts of the stream from station 6 to station 16 may become dry in certain seasons. It was thought that under normal flow conditions the distribution of invertebrates would not be subject to rapid changes, and that bi-monthly sampling would be appropriate. More frequent sampling may become necessary during periods when parts of the stream dry out and on the later resumption of flow. Mapping will include stations 1 - 9 only, since above this station the stream runs as a ditch normally lacking macrophyte growth. The maps will enable both longitudinal and seasonal changes in habitat types to be studied.

The first complete mapping and sampling procedure took place in February 1972. Fifteen of the stations were found to hold water and were therefore sampled with pond nets. The flow from the quarry (16) went underground downstream of station 15, leaving station 14 dry. However, aquatic species were found in soil samples from station 14 and these were recorded. Chieveley Sewage Farm provided water for the resumption of flow at station 13.

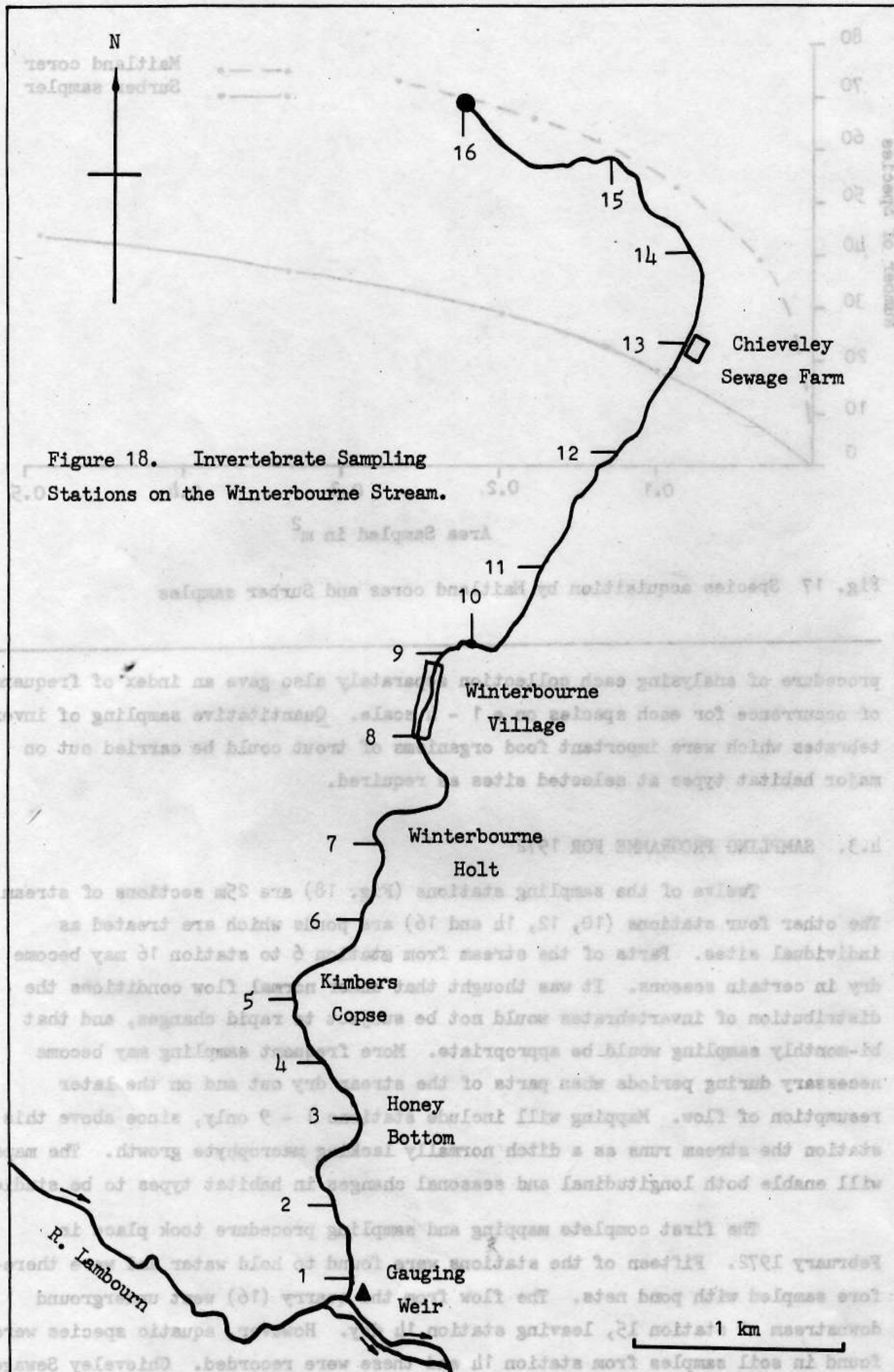


Figure 18. Invertebrate Sampling Stations on the Winterbourne Stream.

The invertebrate samples taken during February have all been sorted, and the identification of all groups except Diptera has been completed. The results (Fig. 19) (exclusive of Diptera) show a marked reduction in the number of species captured from station 1 to station 6. Above this station the results become rather variable due to changes in species composition associated with the intermittent stream and pond habitats. Table 13 gives examples of species in the four samples at each station. All of the Hirudinea are confined to permanent water, whereas some members of the Gastropoda occur in the more temporary-habitats further upstream. Although <u>Gammarus</u> is restricted to permanent water, it has been able to colonise the stream up to station 12. <u>Baetis</u> has the widest distribution of the stream living Ephemeroptera, but further upstream <u>Cloeon</u> occurs in some of the ponds.

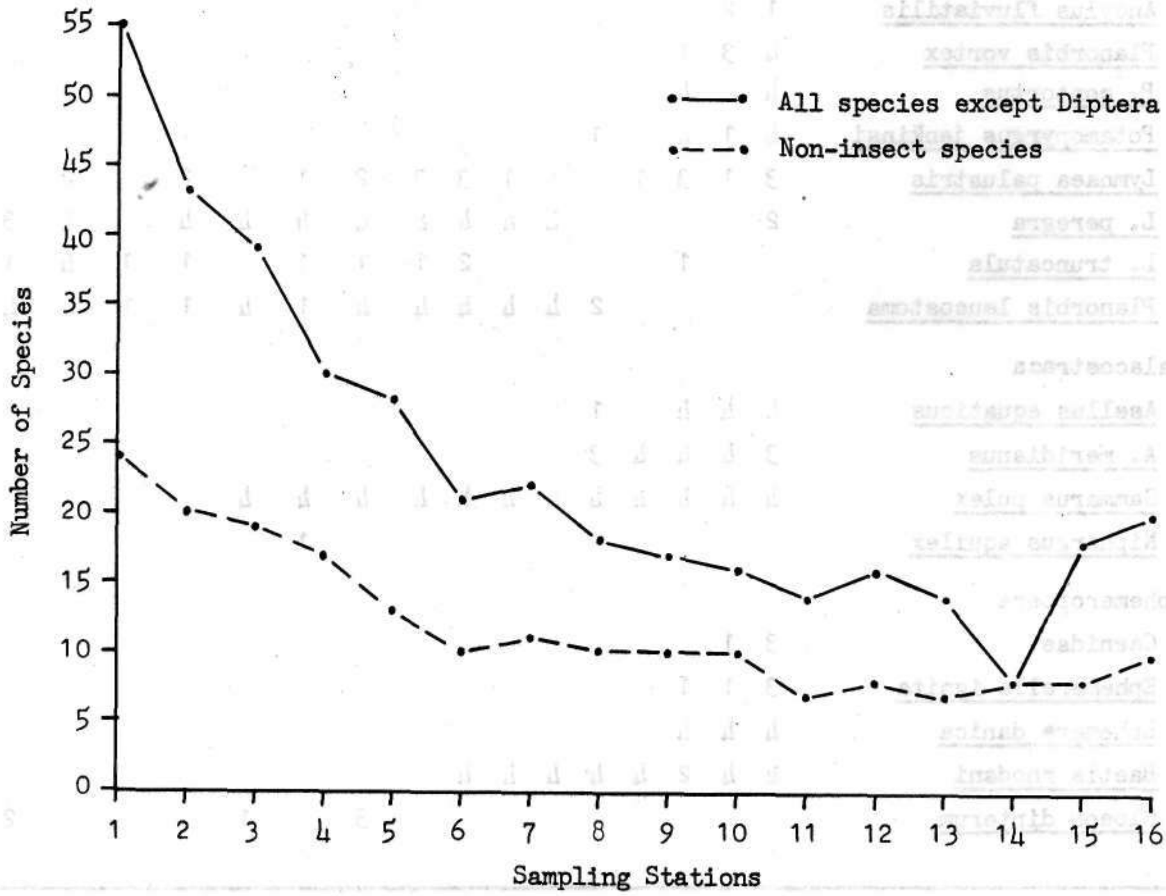


Figure 19. Number of Species taken in One 5-minute Sample at each Winterbourne station, February 1972.

TABLE 13. Number of Occurrences of Species at each Winterbourne Site out of a Possible Total of Four.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Hirudinea																
<u>Theromyzon tessulatum</u>	2	1	1													
<u>Glossiphonia complanata</u>	4	3	4	4	4											
<u>Piscicola geometra</u>	4	4	4	4	4											
<u>Helobdella stagnalis</u>	3	4	2	4	1											
<u>Erpobdella octoculata</u>	3		1	1	1	1										
<u>Trocheta subviridis</u>			1	1		1										
Gastropoda																
<u>Physa fontinalis</u>	4															
<u>Ancylus fluviatilis</u>	1	2														
<u>Planorbis vortex</u>	4	3	1													
<u>P. contortus</u>	4		4													
<u>Potamopyrgus jenkinsi</u>	4	1	4	3	1											
<u>Lymnaea palustris</u>	3	1	3	1			1	3	3	2	1		2		2	
<u>L. peregra</u>	2					4	4	4	4	4	4	4	4		2	3
<u>L. truncatula</u>			1					2	1	1	1		1	1	4	1
<u>Planorbis leucostoma</u>					2	4	4	4	4	4	1	4	1	1	4	4
Malacostraca																
<u>Asellus aquaticus</u>	4	4	4		1											
<u>A. meridianus</u>	3	4	4	4	3											
<u>Gammarus pulex</u>	4	4	4	4	4	4	4	4	4	4	4	4				
<u>Niphargus aquilex</u>											1					3
Ephemeroptera																
Caenidae	3	1														
<u>Ephemerella ignita</u>	3	1	1													
<u>Ephemera danica</u>	4	4	4													
<u>Baetis rhodani</u>	4	4	2	4	4	4	4	4								
<u>Cloeon dipterum</u>										3		1				2

5. THE FOOD OF INVERTEBRATES IN THE LAMBOURN

5.1 INTRODUCTION

The primary aim of the first year's research (February 1971 to January 1972) was to examine the feeding relations of Invertebrates in the River Lambourn as the first phase of an investigation into aspects of the structure and function of the invertebrate community. In essence two interrelated questions were being asked:-

a) On what are the most important species feeding and how does the composition of the ingested food of each species change with its size, the time of year and substratum?

b) What are the relative contributions of the available food resources to the economy of the community?

Information on the food of invertebrates was obtained primarily from monthly analyses of gut contents of animals taken from the river at Bagnor. For comparison, a series of three-monthly samples was taken from two additional stations, one at Elton further up the River Lambourn, and the other on the Winterbourne stream. To supplement these data an investigation into the distribution and abundance of food potentially available for invertebrates (herbivores) was undertaken. Initially this was restricted to a qualitative study of the algae but from January 1972 it was extended to include a quantitative analysis of both algae and detritus in the system. Using this information it may be possible to correlate variations in the diet of a species with food availability in the environment.

5.2. FOOD POTENTIALLY AVAILABLE IN THE ENVIRONMENT

5.2.1 Methods

The qualitative sampling programme for algae, which started in February 1971 involved monthly collections of samples of flints, surface detritus and macrophytes from a small area of river (50 m^2.) at Bagnor. At Elton and on the Winterbourne the period between samples was three months. Flints for examination were removed from the stream, surface detritus sampled by means of a pipette, and macrophyte samples collected by carefully removing a series of randomly selected lengths of stem from each of three beds of <u>Ranunculus</u>, <u>Callitriche</u> and <u>Berula</u>. All samples were preserved in 5% formalin in the field. On return to the laboratory the algae associated with the various substrata were removed by a combination of washing and brushing. The resulting suspensions of algae and detritus were transferred to large measuring cylinders and left for 24 hours to effect sedimentation. The supernatant was then removed and the sediment re-suspended to give a concentration of algae suitable for counting under the high power objective of a compound microscope. The relative abundance of the most Important species was estimated by counting 100 of the commonest species and recording the numbers of other species also encountered. Relative abundance was expressed as a percentage of the total number of cells counted. The algae other than diatoms which were associated with flints could not be estimated in this way but the species were identified and an estimate of effective cover made.

From January 1972 onwards sampling for algae and detritus was quantified. The procedure was essentially as above except that the final value of re-suspended material was measured and the numbers and area of both diatoms and detritus particles determined using a Lund nannoplankton counter. They were then related to the surface of the parent substratum.

5.2.2. Results

It is clear from the qualitative studies on the composition of the main algal associations on gravel, detritus and macrophyte that the system supports a limited number of species of diatoms whose relative proportions change with time. The situation with regard to non-diatom algae associated with gravel is less clear.

The epilithic community

Figure 20 represents a typical cross section of river bed. The type of algal association developing here is determined in part by the size of flint pebbles and rocks comprising the substratum and varies with the season. Thus sand is relatively sparge with respect to algae except for a small epipsammic diatom component while the larger flints exhibit a rich algal community comprising Cladophora, Gongrosira, Chaetophora, Ulvella, 0scillatoria/Phormidium, Chamaesiphon, Hildenbrandia and Batrachospermum. The more common pebbles of intermediate size harbour a flora rather less well developed. Ulvella is usually the dominant green alga> with only small areas occupied by the encrusting form Gongrosira, Diatoms seem to be more abundant in the neighbourhood of these encrustations.

In winter and early spring the dominant association appears to be Ulvella/Cocconeis/Navicula with some Cladophora on larger, more stable flints. Numbers of diatoms at this time are low but in April there is a dramatic increase with a peak of approximately 500,000 diatoms/cm^2. All diatom species apparently contribute to the total increase in numbers but Synedra and Diatoma, relatively unimportant or even absent in February,are particularly important. There is a return to the Cocconeis/Havicula association in June. At this time Cladophora is increasing as is Spirogyra but perhaps more important as potential food for invertebrates is the development of Gongrosira which appears to be at its peak in late summer.

The epiphytic community

In general, the same diatom species occur on macrophytes as on the

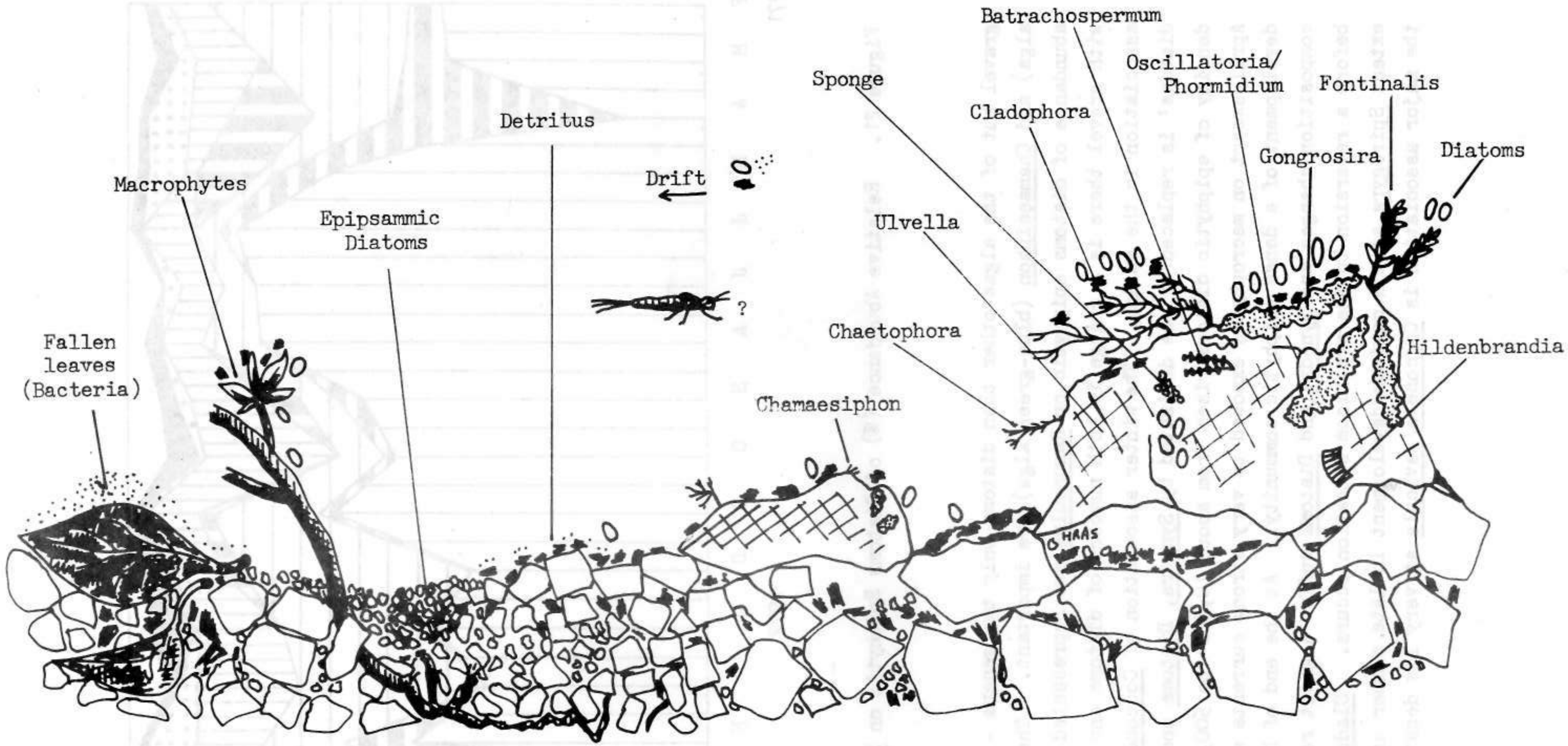


Figure 20. Food Potentially available to Invertebrates on Gravel.

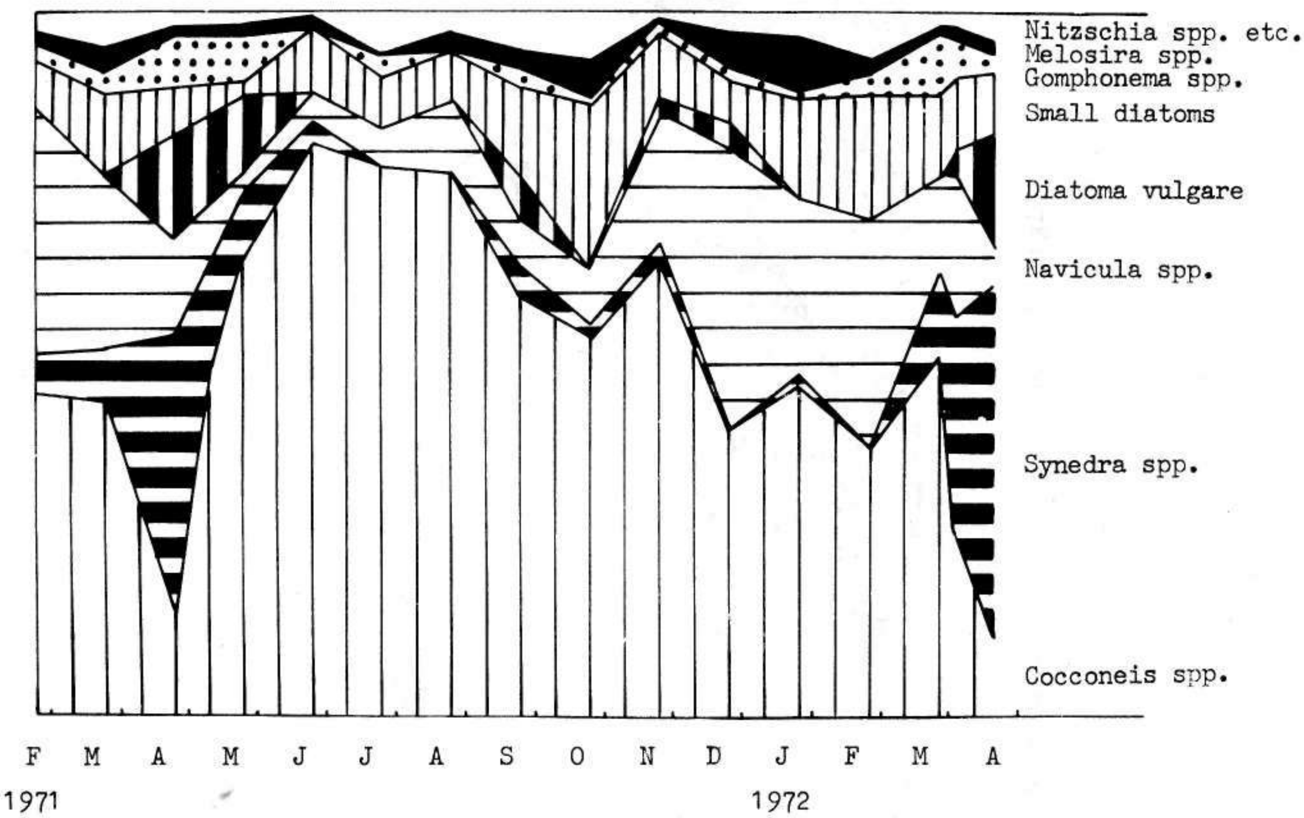


Figure 21. Relative Abundance (%) of Diatoms Epiphytic on Ranunculus.

gravel but of the algae other than diatoms only two genera - Protoderma (green alga) and Chamaesiphon (blue-green alga) are important. The changes in relative abundance of diatoms epiphytic on Ranunculus are represented in Figure 21. As with gravel there is a change in both numbers of diatoms and in the dominant association in the spring. The winter association of Cocconeis/Navicula/ 'small diatoms' is replaced by one dominated by Synedra, Diatoma and Cocconeis. The density of epiphytic diatoms rises from about 10,000+ to 500,000+/m^2 during April except on macrophytes exposed to very strong currents which prevent the development of a dense epiphytic community. At the end of May the species composition changes and Synedra and Diatoma suffer a great reduction in numbers before a reversion to the pre-bloom situation occurs. Cladophora and to a lesser extent Spirogyra attain maximum development in late summer and autumn. In winter the major association is Cocconeis/Navicula at very low densities.

Detritus

The information available on the distribution and abundance of detritus associated with gravel and macrophytes is as yet inconclusive and is not presented. The detritus beds represent a large potential source of food in themselves but the inherent instability of the beds particularly in regions of fast flow restricts the development of a rich diatom flora.

5.3. GUT CONTENTS OF INVERTEBRATES

5.3.1. Methods

Samples were collected at monthly intervals at Bagnor and every three months at Elton and from the Winterbourne. A standard F.B.A. pond net was used to sample each of the three main substrata recognised:

1) gravel (where a 'kick' sampling technique was adopted)
2) detritus including *Berula* (where the net was used as a scoop)
3) *Ranunculus* and *Callitriche* (sweep netted).

Collections were made at approximately 10 a.m. when it was found that the guts of all the species investigated were full. Samples were preserved in 5% formalin, in the field to prevent digestion of gut contents. Each month up to 50 species of the commonly occurring invertebrates sampled were analysed. Extraction of the gut contents of most species was effected after decapitation by gently extruding the contents of the foregut with a seeker. The resulting suspension was examined using a compound microscope. Three broad food categories were recognised as shown below;

1) Detritus
   a) fine organic material and grit (particle size < 0.05 mm.)
   b) coarse organic material (particle size >0.05 mm.) including allochthonous and autochthonous particles which were distinguished where possible.

   'Fresh' plant material was also recorded under this category.
2) Algae
   a) diatoms
   b) other algae
3) Animals

The proportions of each food category were estimated on a percentage cover basis with the aid of an eye-piece graticule which effectively divided the field of view into 100 squares. An estimate was made at low power (x 80) followed by ten random fields examined at x 320. The commonly occuring diatom species were recorded and their relative abundance estimated.

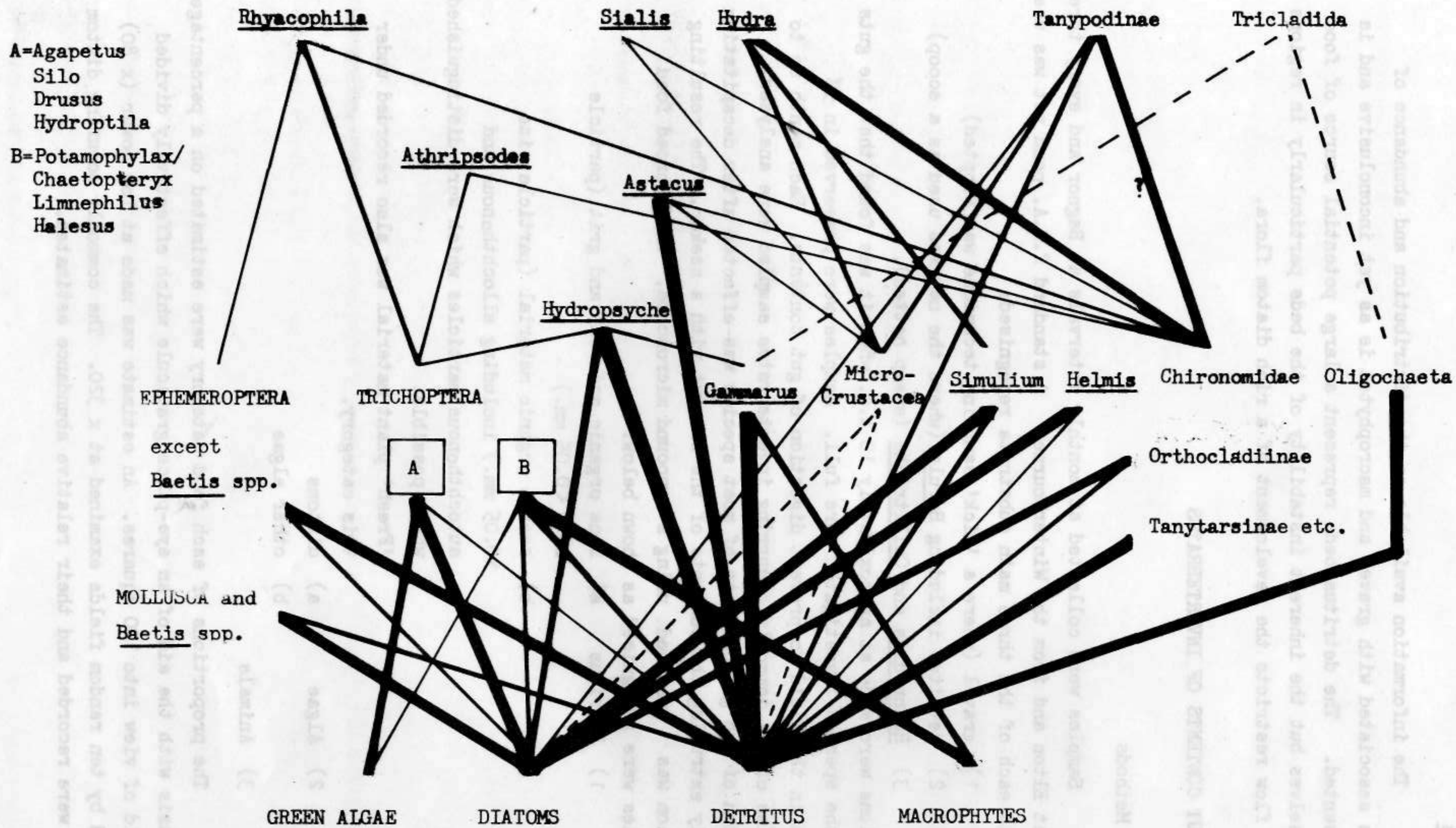


Figure 22. Feeding Relations of Invertebrates in the Lambourn at Bagnor. (May 1971).

5.3.2 Results

It has been necessary for the purposes of this report to synthesize a substantial amount of information comprising some 7,000 observations on up to 50 species. This has been achieved as follows:

First, the raw data on the diets of all the species investigated has been processed to produce the average monthly gut contents composition of the different size-groups (where appropriate) of each species for all substrata.

Secondly, by combining these results an average monthly figure for each species in the river as a whole (substrata and size-groups combined) has been computed. This helps to establish the role of the animal, with respect to its food requirements, in the economy of the community and allows direct comparisons to be made between species, as shown in the food-web diagram (Figure 22). It also permits each species to be ascribed to a particular feeding category of which four are recognised:

1) Detritivore
2) Algal grazer
3) Macrophyte browser
4) Carnivore.

The results of the first year's research are discussed within this framework.

a) Detritivores

It is apparent that the majority of species investigated including the numerically dominant groups are largely dependent on detritus as a food resource. These include Gammarus, all the Ephemeroptera except for certain Baetidae in the spring, Simulium (except spring), most of the Chironomidae, the Oligochaeta and Mollusca. The Trichoptera, a group about which it is difficult to generalise, tend to show less dependence on detritus with the exception of the larger Limnephilidae which may ingest a certain amount of allochthanous material.

The most important species in this category is undoubtedly Gammarus which is essentially herbivorous with a preference for decaying plant tissue both allochthonous and autochthonous (Figure 23). On average, fine detritus (particle size <0.05 mm.) comprises the bulk of food found in the guts. How much of this material is the result of mastication of larger particles is uncertain. Coarse plant detritus assumes more importance in larger animals (> 5 mm.). There would appear to be a preference shown for decaying macrophyte tissue by animals living among macrophytes while those dwelling in gravel or detritus ingest more allochthonous material. Autumn leaf fall apparently provides an alternative rather than an additional source of food and Cladophpra, at its peak of development at this time, is also exploited, particularly by larger animals.

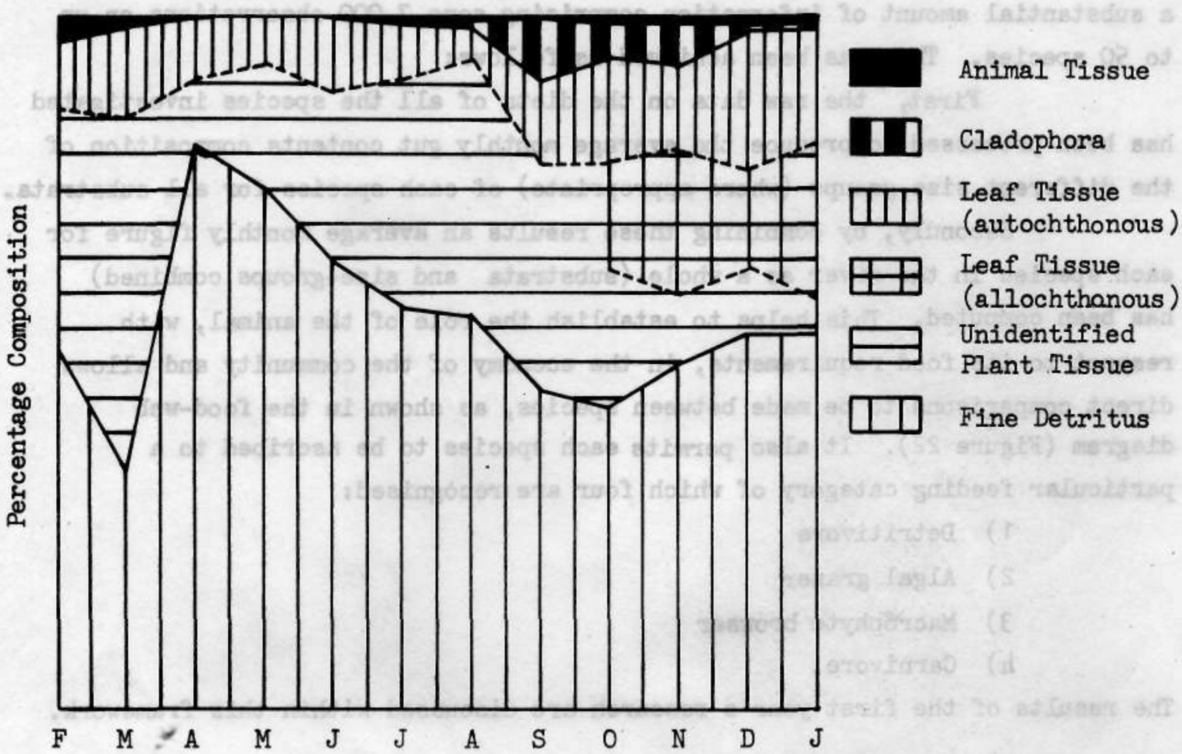


Figure 23. Composition of Ingested Food of Gammarus pulex (mean of all size groups and substrata).

b) Algal grazers

The number of species capable of exploiting algae throughout the year is limited and includes Baetis rhodani (Ephemeroptera); Agapetus spp., Silo sp. and Drusus sp. (Trichoptera); and Helmis sp. and Lathelmis (Coleoptera). Diatoms form the bulk of ingested food in the spring with various green algae including Ulvella and Gongrosira providing an alternative during the rest of the year. (It is of course a pre-requisite that those species requiring the green algae specified should be adapted or adaptable to life on a gravel substratum.

There are, however, a number of species capable of supplementing an essentially detritus diet with diatoms during the temporary abundance in the spring. Included in this group are other members of the Baetidae; many of the Trichoptera; Simulium spp. and some Orthocladiinae (Diptera); and many of the Mollusca. The diatom species taken at this time are generally those most commonly occuring in the system particularly Synedra, Cocconeis and Diatoma.

c) Macrophyte browsers

Relatively few species appear to ingest live macrophyte tissue. Of the Trichoptera, Lepidostoma, Potamophylax/Chaetopteryx, Halesus and Limnephilus lunatus are important but this resource does not constitute the only food supply since dead leaves and algae are also taken. Gammarus only rarely contains fragments of fresh macrophyte tissue. Prodiamesa (Chironomidae), although essentially a detritivore, has on several occasions been found with fresh macrophyte tissue in the gut.

d) Carnivores

There are few species of invertebrate carnivores. Rhyacophila and Polycentropus (Trichoptera), Sialis (Megaloptera), Tanypodinae (Chironomidae), Hydra and Erpobdella (and other Hirudinea) are the most important. Chironomids, microcrustacea, oligochaetes and trichopteran larvae are the most commonly occuring prey in these groups (see figure 2%).

5.4 FUTURE PLANS

To summarise, plant detritus is the major food source for invertebrate primary consumers in the system. Diatoms may be important in providing an alternative food supply for many species during the spring. Green algae, and less commonly blue-greens and reds,are exploited to a small extent by certain of the gravel dwelling species as an alternative to diatoms.

Research is presently being carried out to examine the micro-distribution and abundance of algae and detritus in the system to supplement gut-content analysis. This will continue for a further 12 months but the major part of future research will be concerned with the effect of Gammarus on its food resources including its contribution to the breakdown of detritus in the system and its efficiency of assimilation of the various foods comprising the diet.

6. STUDIES ON TROUT AND GRAYLING

6.1 POPULATION STUDIES

6.1.1. Sites and Programme

A number of fishing sites, usually 50-100 m. long, have been selected to represent a variety of conditions. The programme started with a nucleus of 3 sites at Weston, Woodspeen and Bagnor which had been studied during the 1967-70 project. The number has been increased gradually until seven sites are now under observation. Four of these are at Bagnor; three being population study sites in unshaded, partially shaded and heavily shaded areas respectively. The fourth site is at the lower end of our water where the river is too wide to obtain reliable population estimates by the usual method. This site is used to catch fish for the diet and fecundity studies without disturbing the populations at the other sites. It is an interesting site because it generally contains a higher proportion of grayling than the other sites and it provides the most useful returns of marked grayling. The sites at Weston and Woodspeen provide examples of areas higher up the Lambourn and a site on the Winterbourne has been added to compare the population there with that of the main river.

The population sites are fished every second month. The lease of the water at Bagnor began in January 1971 and fishing should have started the following month. However, the dredging operation mentioned earlier made the water very turbid, reducing visibility to such an extent that it was impossible to fish effectively during most of February and March 1971. Consequently the programme began in April 1971 when the original sites at Weston, Woodspeen and Bagnor were fished together with a second site at Bagnor. Two more sites at Bagnor were added in August and a site on the Winterbourne at Honey Bottom came into use in February 1972. The sites at Weston and Woodspeen are not fished during the winter to avoid any risk of affecting the breeding success of the trout there.

6.1.2. Methods

Samples of fish are obtained by electric fishing using a portable generator to produce a pulsed D.C. output. Stop nets are placed at each end of the site which is then fished twice in an upstream direction. The second fishing allows the fishing efficiency to be determined and an estimation can be made of the total population in the site. Occasionally more repeat fishings are carried out to obtain an additional check on this method of estimating the population.

The fish are retained in baskets in the river until they are examined and they are usually lightly anaesthetized before examination to reduce the risk of injuries in handling. The length to the fork of the tail is recorded. Most fish are also weighed and have a sample of scales removed for age determination. They are then allowed to recover from the anaesthetic before being released.

In August 1971 the northern channel at Bagnor was fished from bottom to top over a period of 3 days and all the fish which were captured were marked by jet inoculation of a dye before being released. Samples of fish obtained at the four population sites shortly afterwards showed the proportion of trout and grayling which had been marked and enabled an estimate to be made of the total populations.

In December 1971 a similar marking operation was carried out in the Winterbourne from above Station 2 (Figure 18) to about halfway between Honey Bottom and Kimber's Copse (Station 4, Figure 18). In January 1972 the Winterbourne was fished again as far up as Kimber's Copse and this provided recapture data on the marked fish. The fish in the Winterbourne were marked in a different position from those in the Lambourn so that they can be distinguished later.

6.1.3. Results from population sites

The numbers of fishings and of fish caught during the period are shown in Table 14. This shows that the average catch per site fished was

TABLE 14. Numbers of sites fished and of fish caught.

Month	No. of sites fished	No. of trout examined	No. of grayling examined
April 1971	3	140	24
June 1971	4	184	17
August 1971	5	304	32
October 1971	6	206	52
December 1971	4	122	78
February 1972	5	127	102
Total	27	1083	305

40 trout and 11 grayling. However, 145 of the grayling were recorded on the 3 fishings of the Bagnor Farm Site where grayling are most numerous. If allowance is made for this, the average number of grayling is reduced to 6 and

it is unlikely that grayling are numerous enough at the other sites to provide reliable data for individual sites although they may give reasonable data if all the sites are combined. Very few 0+ (fingerling) grayling have been caught and this must indicate that they fail to respond to the electric field. In the case of trout, 0+ fish are caught less efficiently than older age groups but reasonable numbers are obtained. The numbers of trout should be adequate to produce reliable data on population density, age structure, length-weight relationships and biomass. However, there has not yet been any opportunity to examine the scales and analyze the data which has been collected in the field.

6.1.4. Results of marking in the Lambourn

The mark-recapture study on the main river in August 1971 produced data of immediate interest. A total of 333 trout over one year old were marked and the numbers recaptured at the four population sites are shown in Table 15. This provides an estimate for the total population in the north

TABLE 15. Recaptures of marked trout over one year old at Bagnor in August 1971

Site	Total catch	Marked fish recaptured	
		No.	Percentage
Upper	41	30	73
Bridge	19	13	68
Lower	32	12	38
Farm	12	9	75
Total	104	64	62

channel of 541 trout excluding 0+ fish. At the same time 115 grayling over one year old were marked and the numbers of recaptures for this species are shown in Table 16. This indicates a total population of 444 grayling excluding 0+ fish. It is apparent from the tables that the efficiency with which trout and grayling were caught for marking was quite different and this reflects differences in the behaviour of the fish. Trout tend to shelter in clumps of weed and remain there until they are drawn out by the electrode. Some, however, are stunned among thick weed and not captured. Grayling move about more during fishing operations, tending to keep out of range of the electrode and then to escape downstream in a sudden rush. They are less likely to escape during fishing at the population sites when stop nets are used and the site is fished

TABLE 16. Recaptures of marked grayling over one year old at Bagnor in August 1971

Site	Total catch	Marked fish recaptured	
		No.	Percentage
Upper	4	1	25
Bridge	1	0	0
Lower	3	0	0
Farm	50	14	28
Total	58	15	26

twice, but they are certainly more difficult to study than trout.

The length-frequency distribution of the trout captured during the marking operation is shown in Fig 24(A). The 0+ age-group is clearly demarcated with a mean length of about 8 cm. and the 1+ and 2+ fish also show quite clearly with mean lengths of about 19 cm. and 2$ cm. respectively. The fact that 1 + fish were more numerous than 0+ fish in the catch is probably due to the lower efficiency of catching fingerlings. Only about 5% of the trout are over 32 cm. in length and it will be interesting to see if this proportion increases while angling pressure is removed from this part of the river.

The length-frequency distribution of the grayling captured during the marking operation is shown in Fig 24(B). The almost complete absence of fingerlings is obvious and the 1+ age group shows clearly with a mean length of about 20 cm. A higher proportion of the population is in the larger size-groups than in the case of trout.

6.1.5. Results of marking in the Winterbourne

The mark-recapture operation in the Winterbourne in December 1 971 and January 1972 showed that the population structure in this stream is different from that in the Lambourn. The length-frequency distribution of the trout examined in January is shown in Fig 24. The inset black histogram indicates the fish in the catch which had been marked in December. Fingerlings are the dominant age-group in this small stream. The proportion of fish over two years old is small but some large fish are present. The marking returns show that the efficiency of catching large fish is high but only about 50% of the fingerlings had been captured in December. Thick beds of water cress at the side of the stream probably concealed many small fish which were stunned. No grayling were caught in the Winterbourne.

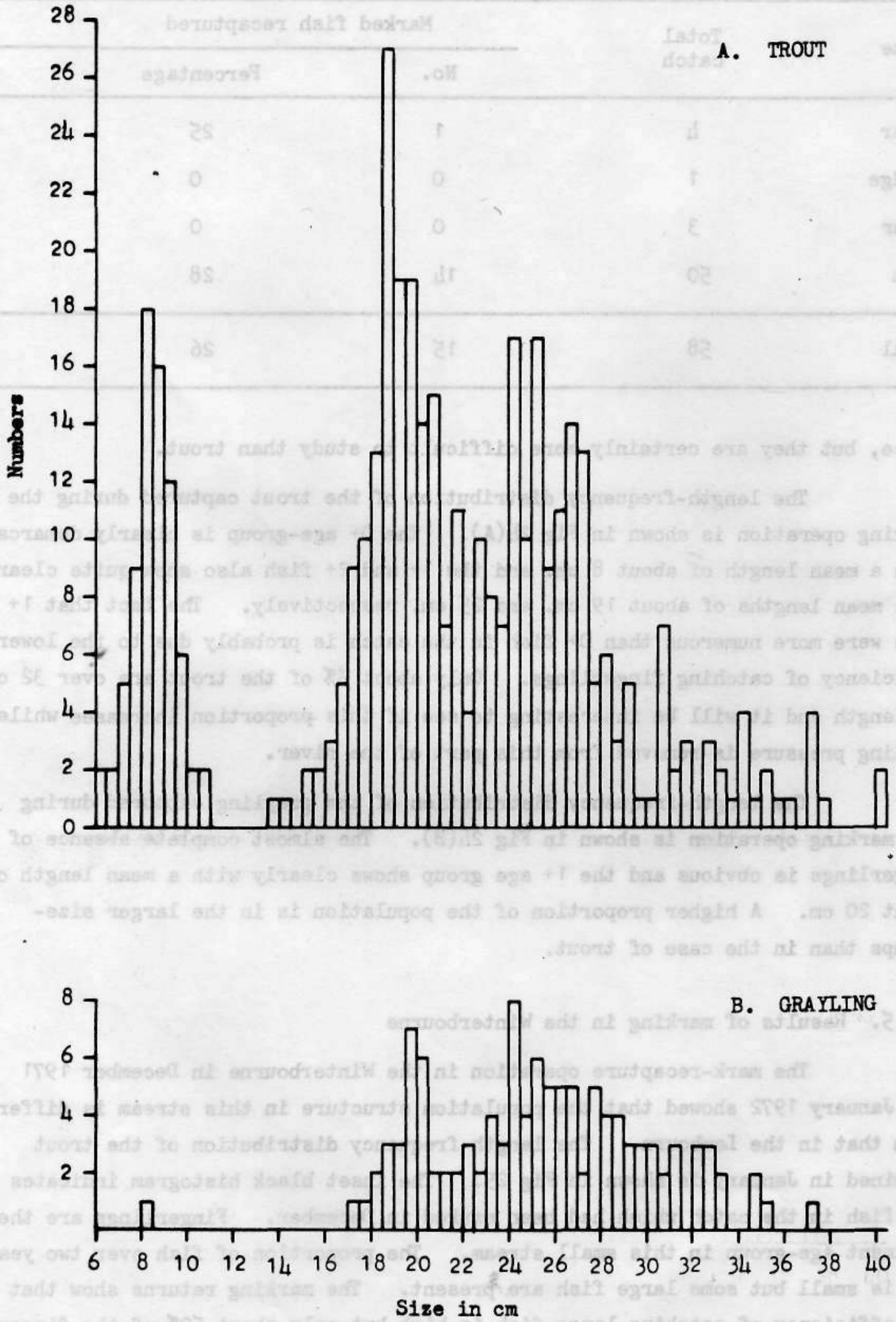


Figure 24. Length-frequency Distributions of A) Trout and B) Grayling in the Lambourn at Bagnor in August 1971

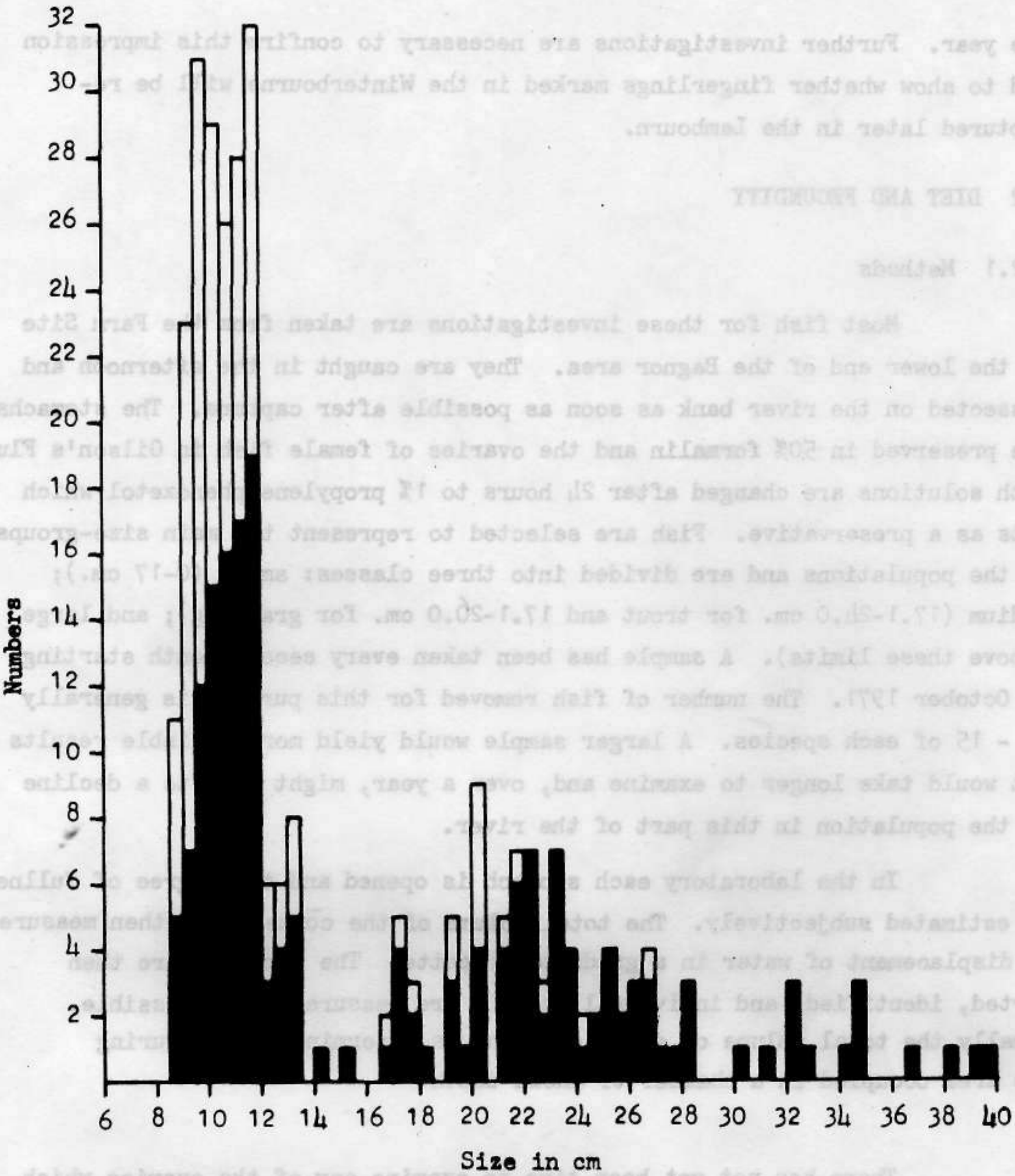


Figure 25. Length-frequency Distribution of Trout in the Winterbourne above Bagnor in January 1972. The black inset shows the recapture of fish marked in December 1971.

Comparison of Figs 24(A) and 25 raises the question of whether the Winterbourne serves as a nursery stream for the Lambourn with mature fish moving up to spawn and young fish colonizing the main river after spending perhaps one year in the tributary. The Winterbourne fishing was carried out during the spawning season of the trout in the hope of finding evidence on this point. None of the fish examined in the Winterbourne had been marked in the Lambourn in August 1971. Since a high proportion of the breeding population for about 800 metres below the confluence had been marked at that time, this suggests that large trout do not move up into the Winterbourne but are resident there throughout the year. Further investigations are necessary to confirm this impression and to show whether fingerlings marked in the Winterbourne will be re-captured later in the Lambourn.

6.2 DIET AND FECUNDITY

6.2.1 Methods

Most fish for these investigations are taken from the Farm Site at the lower end of the Bagnor area. They are caught in the afternoon and dissected on the river bank as soon as possible after capture. The stomachs are preserved in *$0%* formalin and the ovaries of female fish in Gilson's Fluid. Both solutions are changed after 24 hours to 1% propylene phenoxetol which acts as a preservative. Fish are selected to represent the main size-groups in the populations and are divided into three classes: small (0-17 cm.); medium (17.1-24.O cm. for trout and 17.1-26.0 cm. for grayling); and large (above these limits). A sample has been taken every second month starting in October 1971. The number of fish removed for this purpose is generally 10 - 15 of each species. A larger sample would yield more reliable results but would take longer to examine and, over a year, might lead to a decline in the population in this part of the river.

In the laboratory each stomach is opened and the degree of fullness 'is estimated subjectively. The total volume of the contents is then measured by displacement of water in a graduated pipette. The contents are then sorted, identified, and individual animals are measured where possible. Finally the total volume of each component is determined by measuring the area occupied in a chamber of known depth.

There has not yet been time to examine any of the ovaries which have been collected.

6.2.2 Results

A comparison of small, medium and large trout from Bagnor Farm Site in October and December is shown in Figure 26. In October each size group appears to have a different major food item. Small trout were feeding mostly on Gammarus, medium trout on Gammarus and cased caddis and large trout on fish. The chief problem in having five or less fish in each size group is that one stomach which is full of one food item may bias the group results. Thus only two of the large trout were actually feeding on fish at the time of the sampling although it appears on the graph as the chief food item. In October Ephemera danica also was only eaten by large trout.

In December a considerable change in the diet is seen. Small

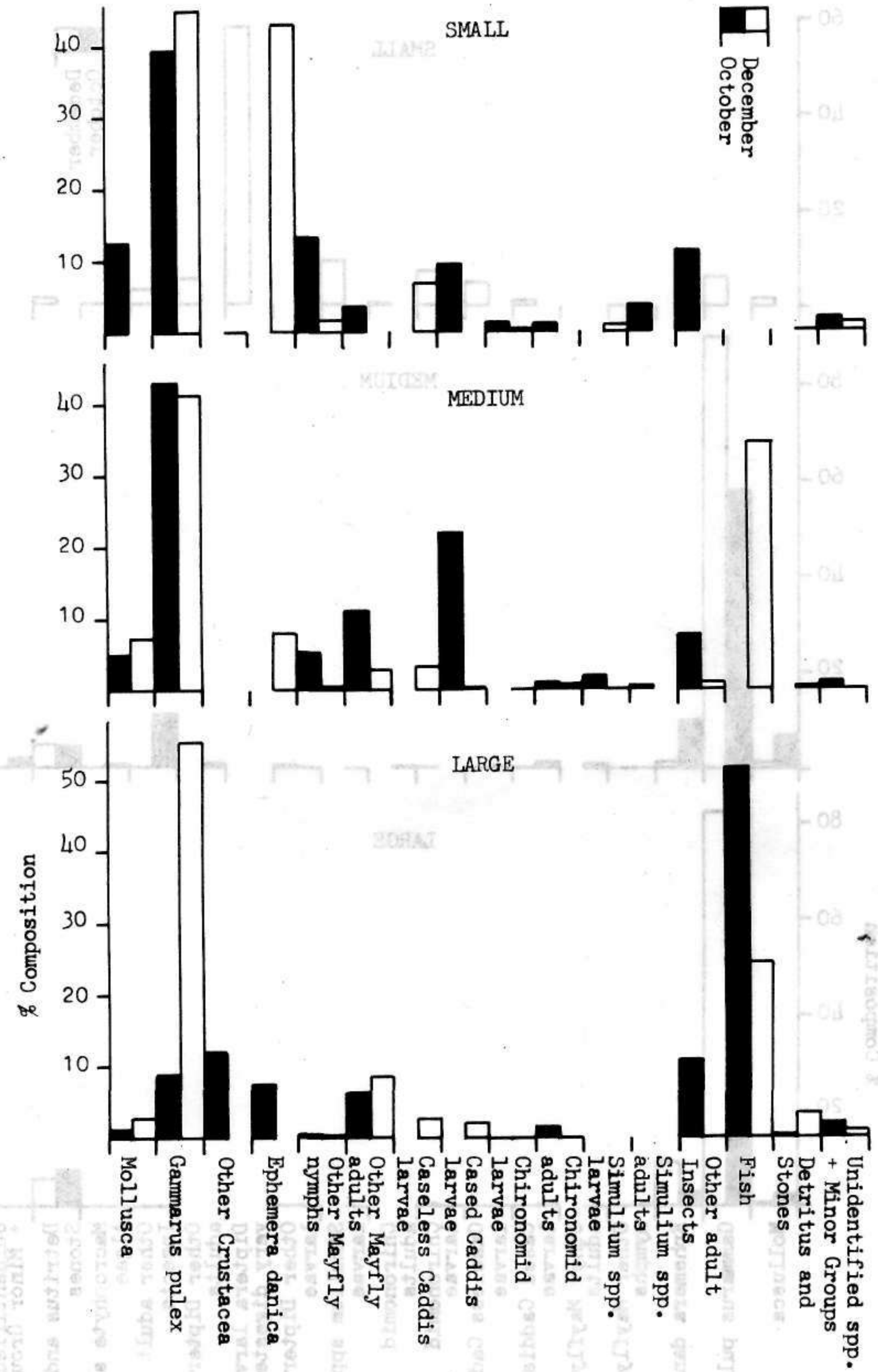


Figure 26. Comparison of the Percentage Composition of the Diet of Small, Medium and Large Trout from Bagnor Farm in October and December 1971.

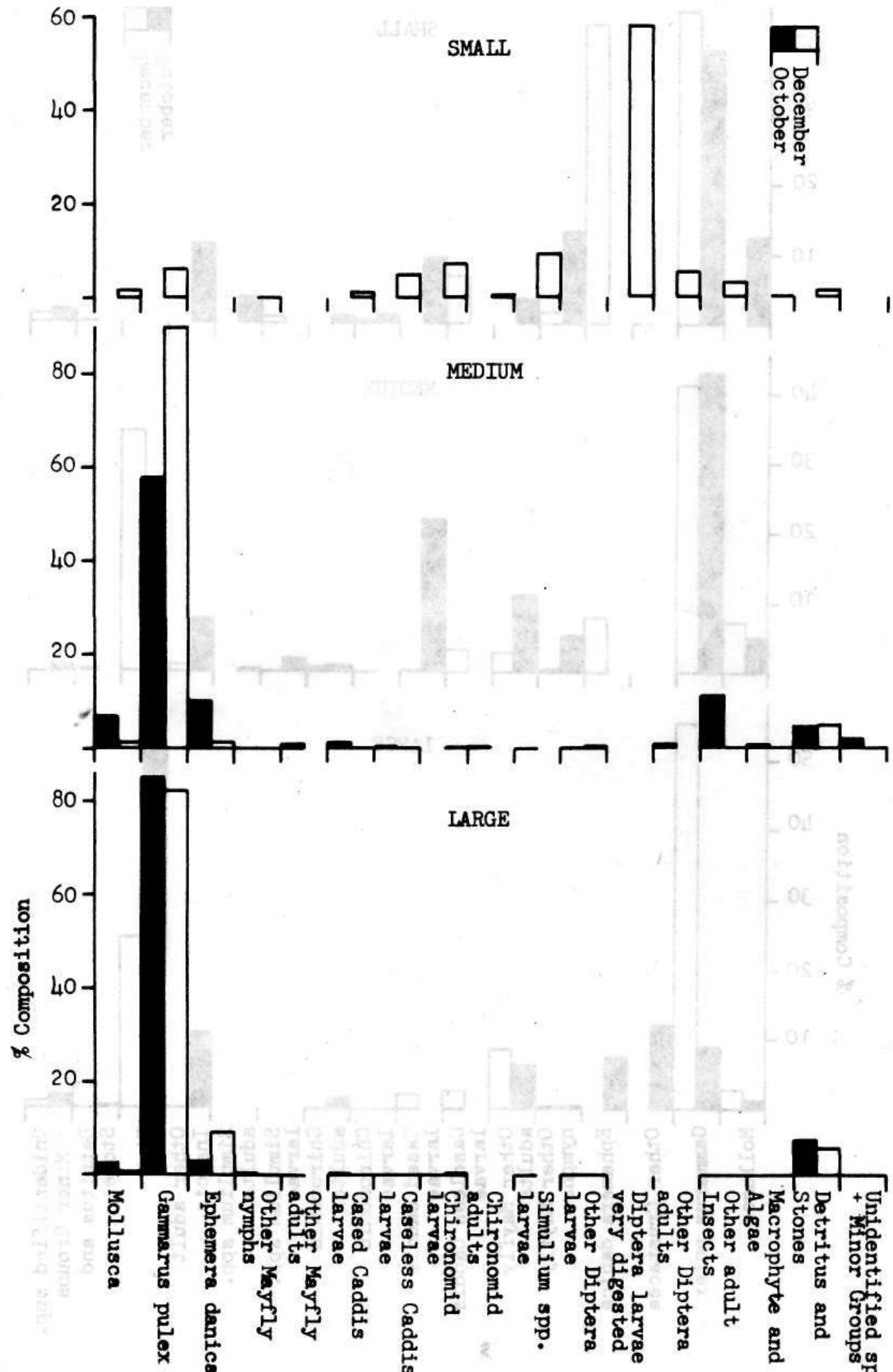


Figure 27. Comparison of the Percentage Composition of the Diet of Small, Medium and Large Grayling from Bagnor Farm in October and December 1971

trout, while continuing to feed on Gammarus, had begun to take Ephemera in almost equal quantity. Adult insects had practically disappeared from the diet in both the small and medium size groups. The medium-sized trout had changed to feeding on Gammarus and small fish although again the latter was only consumed by one trout. The large trout while continuing to eat fish had begun to take Gammarus in large numbers.

Figure 27 provides a similar comparison for small, medium and large grayling. Unfortunately no small grayling were caught in October, and the result for December is based only on one fish. It can be seen that the diets of medium and large grayling were composed almost entirely of Gammarus pulex. This is true both for October and December. In October insects were a fairly important constituent of the diet of the medium size group but these disappeared in December.

The single small grayling examined had a preponderance of Dipteran larvae, and the large unidentified column is composed of the digested remains of chironomid and Simulium larvae.

In October 1971 some young grayling were removed from Weston and Woodspeen and the diet of large grayling from these sites is compared with those from Bagnor in Figure 28.

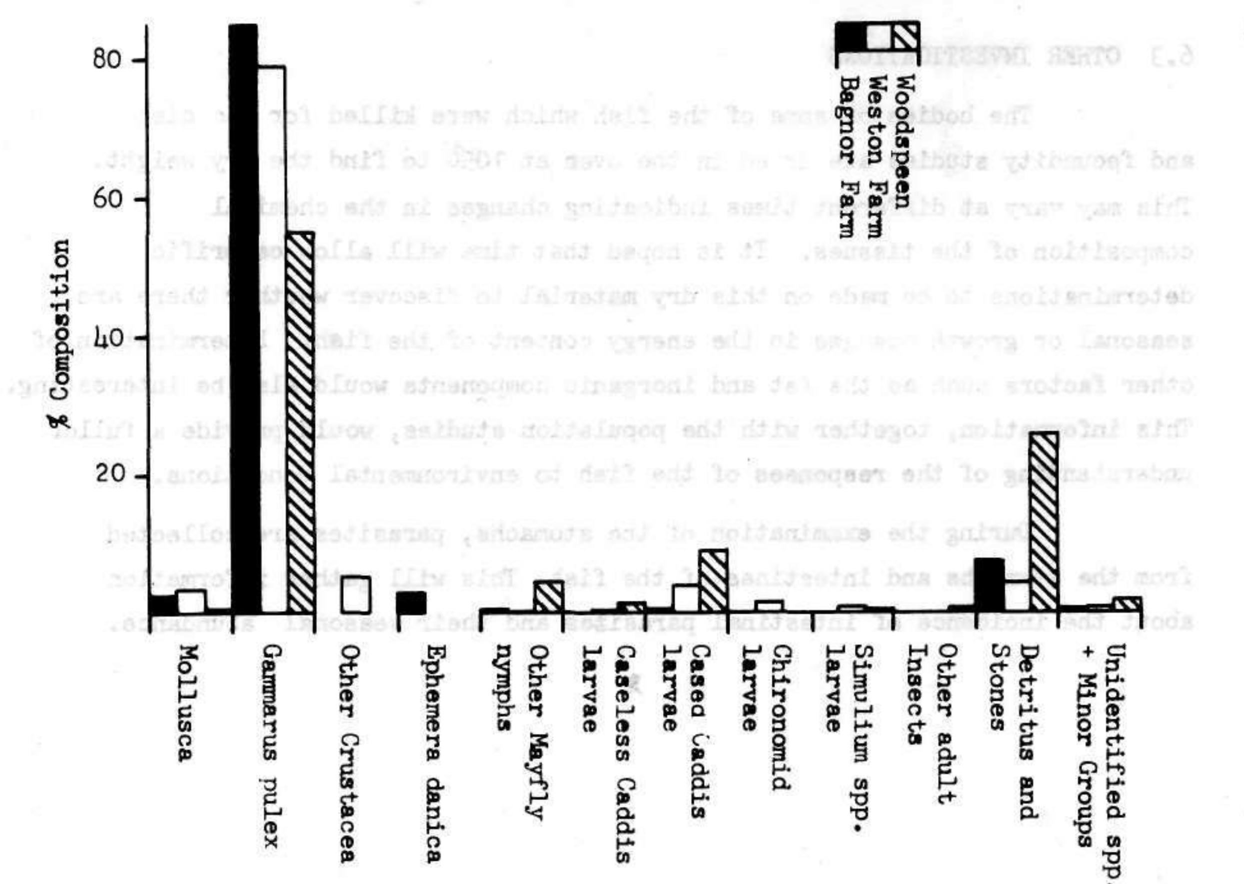


Figure 28. Comparison of the Percentage Composition of the Diet of Large Grayling from Bagnor Farm, Weston Farm and Woodspeen in October 1971.

There is uniformity of the major component (Gammarus) at all three sites, but differences in the subordinate food animals. Thus Asellus features prominently at Weston Farm, Ephemera at Bagnor, and caddis larvae and other ephemeropterans at Woodspeen.

Both trout and grayling appear to be feeding on those organisms which are most available at any one time. The change in the diet between October and December probably reflects a change in abundance of the food animals, a fact illustrated by the disappearance of adult insects from the diet in December.

Selection of the commonest organism is not however the same in trout and grayling. Trout appear to feed more in mid-water or at the surface than grayling, and select insects although Gammarus is probably the commonest organism in the river. The lack of bottom feeding in trout is shown by the near absence of detritus and stones from their stomach contents. These two components increase slightly in volume when the fish resort to organisms such as Gammarus and Ephemera danica nymphs in December, presumably due to the decrease in the number of adult insects.

Grayling on the other hand appear to feed much more on the bottom of the river. Gammarus was the only important food organism, at least for these two months, and because this is abundant all year round very little change is seen between October and December. A high amount of detritus and stones is found in the stomachs of these fish.

6.3 OTHER INVESTIGATIONS

The bodies of some of the fish which were killed for the diet and fecundity studies are dried in the oven at 105°C to find the dry weight. This may vary at different times indicating changes in the chemical composition of the tissues. It is hoped that time will allow calorific determinations to be made on this dry material to discover whether there are seasonal or growth changes in the energy content of the fish. Determination of other factors such as the fat and inorganic components would also be interesting. This information, together with the population studies, would provide a fuller understanding of the responses of the fish to environmental conditions.

During the examination of the stomachs, parasites are collected from the stomachs and intestines of the fish. This will gather information about the incidence of intestinal parasites and their seasonal abundance.

7. STUDIES ON BULLHEADS AND LAMPREYS

7.1. INTRODUCTION AND AIMS

This study concerns itself with three aspects of the ecology of the bullhead (Cottus gobio) and lamprey (Lampetra planeri) in the Lambourn and Winterbourne.

i) Factors affecting distribution throughout the river system and more detailed studies of microhabitat distribution.

ii) Production studies at a number of sites. This work involves the collection of data on growth, fecundity and changes in population density.

iii) Diet studies. The bullhead programme includes three interrelated aspects.

First, a general diet study for 12 months using a sample of 70 fish taken monthly from five different sites on the Lambourn and Winterbourne.

Second, a more detailed 12 month study comprising bullheads from two important but distinct habitat types, using a sample of 20 bullheads monthly from each habitat.

Finally, an investigation into the change in diet from the fry stage to the more typical diet of the bullhead.

So far, work has centred upon the general bullhead diet study but considerable preliminary work has been carried out on most of the other topics. Future work will concern itself primarily with distribution and production studies.

Bullheads and lampreys are collected for this study using the electric-fishing equipment described in the previous section on trout and grayling.

7.2. STUDIES ON THE BULLHEAD

7.2.1. Distribution

The bullhead is widely distributed throughout the permanent parts of the Lambourn and the Winterbourne. It has been found at a number of sites encompassing a marked variety of habitats. Records from the Lambourn include Donnington Grove to Bagnor Mill, (both the north and south channels), Woodspeen, Weston Farm and East Shefford and in the Winterbourne from Bagnor gauging weir to Kimber Cottage.

A major factor affecting distribution within the river system is that of permanent flow. Fishing surveys carried out during the period of December 1971 to March 1972 showed that the bullhead occured throughout the Winterbourne from the gauging weir at Bagnor to Kimber Cottage but not beyond. Since Kimber Cottage appears to be suitable for bullheads, it is possible that they do not occur due to the fact that it is liable to dry up periodically. However, a small weir in the grounds of Kimber Cottage would also probably prevent further colonisation upstream at present. In contrast, both species of stickleback occur quite commonly in the Winterbourne above Kimber Cottage. These probably survive periods of no flow in the various ponds along the Winterbourne which are suitable for sticklebacks but not bullheads.

Bullheads prefer areas where there are large stones or macrophyte such as Berula, which can provide shelter from the current. The species is scarce or absent in areas of bare, open well-compacted gravel.

7.2.2. Estimation of Population Density

The preliminary study involved investigations into population changes of the bullhead at six sites, five on the Lambourn and one on the Winterbourne. Each site consisted of a 3m. long band across the river which was sampled bimonthly from April 1971 to October 1971.

The method involved fishing each site 3 or 4 times consecutively. The total number of fish caught on each fishing was recorded and none were returned to the site until the last fishing was over. Length data on all fish was also recorded before they were returned. An estimate of the total number of fish present in each site could then be made by two methods:

i) The total number of fish caught on each consecutive fishing should decline. By plotting the total number for each consecutive catch against cumulative catch, and drawing a line through the resultant points, the total number of fish in the site is given where this line cuts the x axis.

ii) Using the Seber-Le Cren flormula

$$p = \frac{C_1^2}{C_1 - C_2}$$

where p = total number in the population
C_1 = the first catch
C_2 = the second catch

Using the Seber-Le Cren formula results for three months are given in Table 17.

TABLE 17. Population Density of Bullheads per m^2 at Six Sites

Month (1971)	1	2	Population Sites 3	4	5	6	Mean Density each Month
April	0.35	0.31	0.16	1.34	0.07	-	0.37
June	0.13	0.30	0.21	1.30	-	0.47	0.37
August	1.13	1.65	0.87	1.70	-	0.42	1.13

1. Bagnor site 1.
2. Bagnor site 2.
3. Bagnor site 3.
4. Woodspeen
5. Weston Farm
6. Winterbourne - Bagnor gauging weir

Problems occured with the electric fishing method including decreased accuracy of estimation in mid and late summer due to weed growth and the low efficiency with which bullhead fry less than 2.$ - 3.0cm. were caught.

Nevertheless a number of generalisations can be made. The population remains fairly stable from spring to mid summer, but in late summer there is a marked increase in population density due to recruitment from fry. There is considerable variation between sites. Note particularly the high numbers at Woodspeen and the low numbers at Weston Farm.

Since December 1971 a new approach has been taken with regard to population studies. Eight new sites have been chosen and the previous six sites have been abandoned. Each new site is approximately $50m^2$ in extent, which in most cases is considerably larger than the sites sampled in the initial study. Where the weed is thick and prevents efficient fishing it is thinned out. The results have been more consistent than those previously obtained as shown in Table 18.

TABLE 18. Total Catch after the first two fishings for Bullheads at three sites. Approximate area sampled is $50m^2$.

Site	December 1971	March 1972
Bagnor - Watermill Theatre	247	145
Weston Farm	26	18
Winterbourne - Stag Cottage	175	67

Considerable mortality occurs in the late winter which is associated with the onset of the breeding season. This mortality may be the result of the combination of harsh environmental conditions and the use of energy for gonad development.

7.2.3. Growth

i) Ageing

Ageing is important for distinguishing the different generations (age-groups) present in the population, calculating the proportions of these age-groups within the population and estimating life-span.

Bullheads can only be aged accurately by examination of their otoliths. These are structures made of calcium carbonate which are located in small chambers at the base of the skull. They increase in size as the bullhead grows, producing opaque-white calcium carbonate in the spring and summer and transparent calcium carbonate in the late summer and autumn. By counting these zones under a binocular microscope using reflected light, the age of the bullheads can be calculated.

Otoliths, and associated length and weight data, were obtained from bullheads caught for the diet study. Examination of these otoliths has shown the occurence of three generations in late summer 1971• A 0+ generation, produced in summer 1971, a 1+ generation produced in 1970 and a 2+ generation produced in 1969. It also indicates that the life-span of the bullhead is approximately two years.

ii) Length and Weight Studies

In order to produce an Allen Curve to estimate production, the biomass of each generation of bullheads must be calculated. Since only lengths are recorded from the bullheads caught in the population studies, a method of calculating their biomass is required. Length and weight are recorded for bullheads caught monthly for diet studies. Plotting length against weight, on double logarithmic paper, for each bullhead and drawing a straight line through the points gives a length to weight ratio for that month. By reference to this length to weight ratio, the biomass of bullheads caught in the population studies can be obtained from their lengths. After relating this to the information on age, the biomass of each age group of bullheads can be plotted monthly to produce an Allen Curve.

iii) Growth

Monthly length-weight data for fish whose age-group is known allows growth to be assessed. In all age-groups, this growth occurs mainly during the period May to August and virtually no growth occurs during the winter.

7.2.4. Fecundity and Life History

In spring 1971 a number of ovaries were taken from bullheads, most of which were caught for the April diet study. From these ovaries a preliminary estimate of fecundity (number of ripening eggs per female) was made.

Ovaries were removed from bullheads and placed in labelled 1-dram vials containing Gilson's fluid. Each ovary was categorized as immature, developing or ripe according to the size and shape of the ovary and the colour and mean diameter of the eggs.

The main characteristics of each category were as follows:

i) immature - ovaries small and not distorting body wall; mean diameter of eggs less than 0.5mm. and white in colour

ii) developing - ovary fairly large and distorting body wall; mean diameter of eggs 0.6-1.5mm. and light orange in colour

iii) ripe - ovary very large and distorting body wall to a considerable extent; mean diameter of eggs 1.6mm. and upwards, dark orange in colour.

The total number of eggs present in each ovary was also recorded along with the length and weight of the bullhead.

Some results are shown in Tables 19 and 20.

TABLE 19. Proportion of bullhead ovaries which were immature, developing or ripe at Bagnor at three different times during the Spring.

Date	Immature Ovaries	Developing Ovaries	Mature Ovaries
1st March 1971	40%	60%	0%
1st April 1971	10%	90%	0%
28th April 1971	0%	56%	44%

Table 19 shows the gradual increase in the number of developing and ripe ovaries, whilst Table 20 demonstrates that the mean fecundity for both developing and ripe ovaries is approximately 200. However, additional evidence from other sites suggests that developing ovaries have slightly more eggs than ripe ones and that there is a difference in the mean fecundity of bullheads at different sites. The proportions of immature, developing and mature ovaries at different sites in late April were approximately the same except for Woodspeen which had a substantially higher proportion of immature ovaries. The mean

TABLE 20. Mean Figure for Fecundity at Different Sites, late April 1971. Data from devloping and ripe ovaries.

Site	Developing Ovaries	Ripe Ovaries
Bagnor	222	152
Woodspeen	126	92
Weston Farm	222	367
Mean of three sites	190	200

fecundity of 0+ bullheads (180) was considerably less than that of 1+ bullheads (250). Furthermore, within an age group there was evidence to suggest that smaller fish have a lower fecundity than large fish. The older and larger bullheads developed sooner in the spring than the younger and smaller bullheads. Finally, specimens less than 40mm. at the beginning of the breeding season did not develop ripe ovaries, but remained immature throughout the breeding season.

The first egg batches were found in early April at Bagnor and since the proportion of developing eggs was still 56% in late April the period of laying must extend well into May. Fry would therefore hatch from late May to early July. This may well account for the wide range of size in bullheads of the same generation. The eggs per batch ranged from 144 - 392 with a mean of 220.

A further, more detailed study of fecundity will be made in spring 1972.

7.2.5. Diet

The general diet study started in April 1971 and will continue for 12 months. A total of 70 bullheads are caught each month from five different sites as shown below.

i) Bagnor, near the roadbridge. 20 bullheads from Berula and gravel.
ii) Bagnor, near the Watermill Theatre. 10 bullheads from Ranunculus and gravel.
iii) Woodspeen. 20 bullheads from Berula and Ranunculus with stones and gravel.
iv) Weston Farm. 10 bullheads from Ranunculus and gravel.
v) Winterbourne stream above Bagnor gauging weir. 10 bullheads from detritus with a little gravel.

After collection, the bullheads are processed as rapidly as possible to reduce digestion of food. Each fish is measured and weighed before the stomach is removed and placed in an appropriately labelled vial containing 25% formalin. After 24 hours the stomachs are transferred to 1% propylene phenoxytol. The otoliths are removed from the bodies of the bullheads and placed in vials to dry.

Each stomach is examined individually under a binocular microscope to assess its fullness. This is estimated in terms of empty, ¼ full, ½ full, ¾ full and full. The contents are then emptied into a watchglass and mixed with water before the food items are sorted and identified using a binocular microscope. The volume of each food item is determined by squashing between two microscope slides held 1mm. apart and counting the number of millimetre squares it occupies. After identifying and determining the volume of all food items their relative importance is calculated as a percentage of the total. The stomach contents are then dry weighed. The data is 'pooled' for each monthly sample to give an overall picture of the diet. The diet of bullheads can also be represented by percentage occurence, that is the proportion of stomachs in the sample in which a particular food item occurs. Since stomachs were obtained from a variety of sites it will be possible to assess variation in the diet of bullheads at different sites. The diet of bullheads for the months of April, June and September 1971 is shown in Figure 29. The following comments refer to this figure and also to results obtained more recently.

Gammarus pulex dominates the diet throughout the year, becoming relatively more important during the winter, with the possible exception of June. *Asellus* spp. are relatively unimportant except for a period in mid-winter, whilst *Astacus* was a minor food item in the diet during July and August.

Ephemeroptera are the most important insect group during the summer, particularly in June, when *Ephemerella ignita* is taken in large numbers. Baetidae are the most important group in other months but *Ephemera danica* is very rarely recorded.

Trichoptera are the most important insect group during the winter and second in importance in summer. *Hydropsyche* sp. and *Rhyacophila* sp. are common food items but cased caddis are infrequent in the diet except between January and March.

Diptera, particularly chironomids, are the most important food item in bullheads of the 20 - 40mm. size range in late summer to autumn when most of the fry are of this size. Overall, Diptera, mostly Chironomidae, *Simulium* and Ceratopogonidae, are the third most important insect group.

Coleoptera, *Sialis*, Mollusca, Oligochaeta and Hirudinea all occur in the diet but are of minor importance.

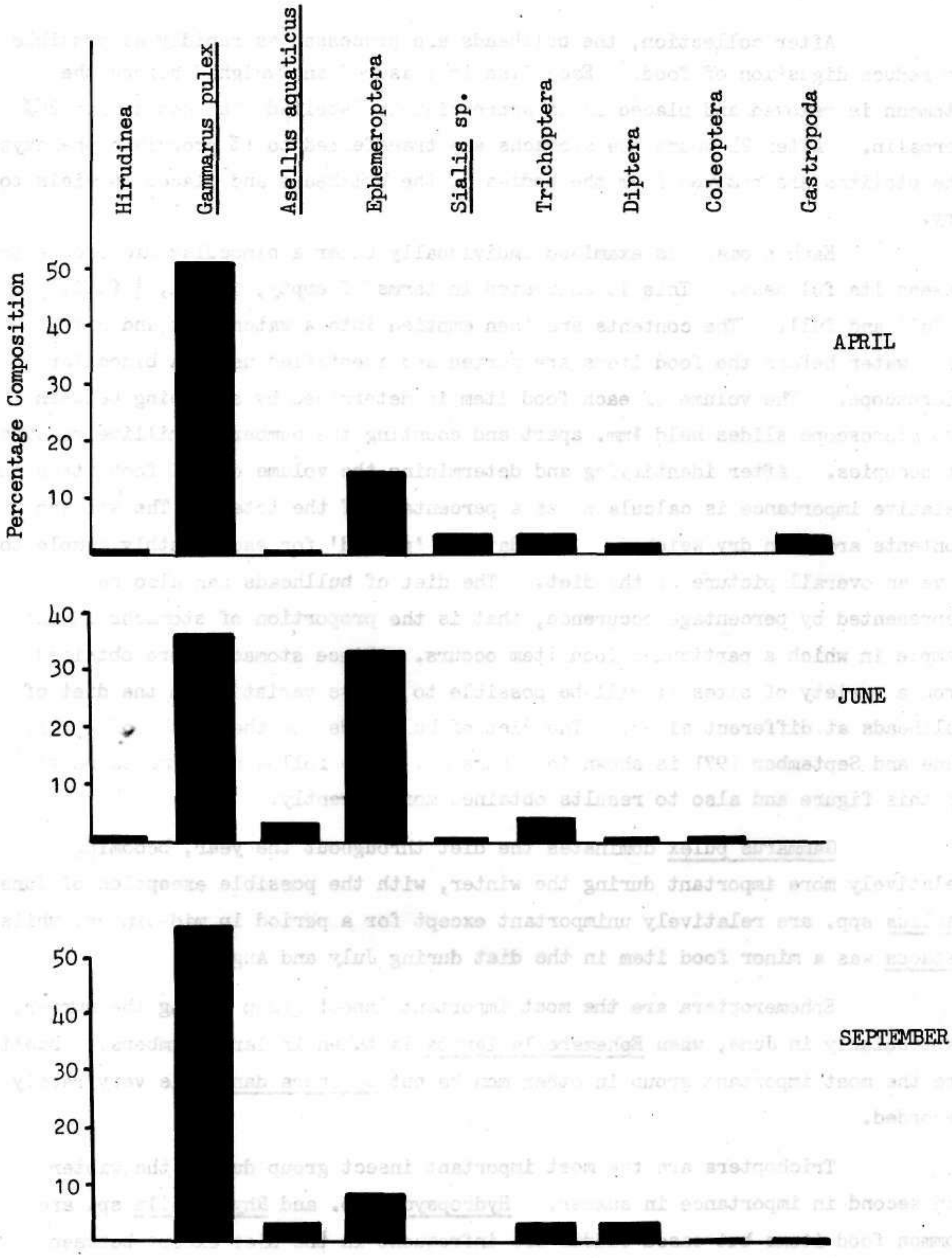


Figure 29. Diet of the Bullhead (Cottus Gobio) in the River Lambourn, 1971.

Examination of the stomachs of two bullhead fry less than 10mm. in length showed that they had eaten microcrustacea. It seems likely therefore that as bullheads develop, their food may change from microcrustacea, through Chironomidae to a diet dominated by Gammarus pulex.

7.3. STUDIES ON THE LAMPREY

7.3.1. Distribution

Ammocoetes of the brook lamprey are locally distributed within the Lambourn and Winterbourne system. They occur where mud has built up under areas of weed such as the Berula at Bagnor, and in places where the substratum consists entirely of mud, such as the southern channel of the Lambourn below the road bridge at Bagnor and above the gauging weir in the Winterbourne. This last locality, where there is also a rich covering layer of course organic detritus and shade from overhanging trees, appears to be a particularly favourable habitat. Ammocoetes have not been found in mud where there is little or no flow of water and where conditions are stagnant. The adult lampreys which appear in spring and autumn are found in more gravelly areas.

Three factors probably determine the overall distribution of the brook lamprey in the River Lambourn and the Winterbourne. These are the presence of suitable mud and silt, a steady flow of water providing oxygen and probably food, and the limit of permanent flow. Since mud and silt within the river system can vary with changes in flow, the distribution of ammocoetes can be changed suddenly and drastically. This is well exemplified by events at Bagnor in 1971. The southern channel of the River Lambourn near the mill had banks of mud along its edges in April and June and ammocoetes were numerous at this time. However, the flow of water through the channel was greatly increased during the summer with the consequent disappearance of the mud and ammocoetes.

7.3.2. Production Studies

Problems have 'arisen over estimating the density of ammocoetes since electric fishing over mud appears to be rather ineffective. Furthermore, the mud substratum is often inaccessible to fishing and unstable due to changes in the flow of the river. These problems make the Seber-Le Cren and cumulative catch graphical methods of estimating the population inappropiate. However, it may be possible to make use of mark and recapture methods in areas of mud which are both fairly accessible and stable in character.

Age, mean weight and growth can be studied by using length-frequency diagrams and length to weight ratios. Since ammocoetes live for five years, length-frequency diagrams should have five distinct peaks relating to each generation or age-group.

In the spring of 1971 only two female lampreys were obtained and their eggs removed to estimate fecundity. It is hoped that more work on these aspects of the ecology of lampreys can be carried out in the future.

7.3.3. Diet

Some work on the diet of the ammocoetes has been completed but not on such a regular basis as that for the bullhead diet study.

The ammocoetes are measured and placed in labelled polythene bags containing 50-70% formalin. Later the guts are dissected and the contents placed in labelled 1-dram vials containing 5% formalin prior to examination under a compound microscope.

In May and June 1971 the gut contents were found to consist of 70$ unicellular algae and 30% detritus. The algal component consisted of 80$ unicellular green algae and 20% diatoms, the commonest genera being Synedra, Navicula and Cocconeis. In contrast, the surface mud in which the ammocoetes were living consisted of 90% detritus and 10% diatoms. The literature on feeding suggests that ammocoetes filter unicellular green algae from the water and these results appear to substantiate this view. Further work on the diet of ammoecoetes is planned for the future.